DTSC's Vapor Intrusion Database: Evaluation of Attenuation Factors for Buildings In California

Department of Toxic Substances Control
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EXECUTIVE SUMMARY

In early 2019, the Department of Toxic Substances Control (DTSC) gathered data from sites contaminated with chlorinated volatile organic compounds (CVOCs) in California to improve its knowledge and understanding of vapor intrusion (VI). The data collected from these sites was used to determine whether subslab, soil gas and groundwater attenuation factors (AFs) that are representative of climatic conditions and types of buildings commonly found in California could be empirically calculated. After the review of the reports from these sites, it was determined that there was sufficient data available to empirically calculate AFs for California. DTSC VI data from these sites presents the most comprehensive compilation of VI data collected to-date for CVOCs in California. Nevertheless, it is important to note that the database, although relatively large, reflects only a subset of the hundreds of VI sites identified in California.

The State Water Resources Control Board (SWRCB) is also planning to develop California-wide AFs in the future and has modified the Geotracker database to gather data to meet its objective. It is hoped that DTSC data will eventually become part of the Geotracker database and state-wide efforts to develop California AFs in the future. Therefore, the statistical distributions of AFs may change when the SWRCB's Geotracker database becomes populated with data from additional sites.

The DTSC VI database includes measurements from 52 sites located in 16 counties across California. The database contains 4,972 paired measurements of which 1,196 (24%) are paired subslab and indoor air measurements, 3,509 (71%) are soil gas (interior and exterior) soil gas and indoor air measurements, and 267 (5%) are groundwater to indoor air measurements. Petroleum compounds were excluded from the database because the constituents are biodegradable, require more complex analysis for deriving the AFs, and are addressed by the SWRCB's Low Threat Closure Policy.

The database was subjected to extensive quality assurance and quality control review by DTSC staff. Since almost all the data was derived from the sites that are overseen by DTSC, project staff were consulted to ensure that data included was adequate, and that pairings were most representative of the VI conceptual site model. Subsequently, data were evaluated to minimize influence of indoor and outdoor background sources by applying 50-times background source strength screen to subslab and soil gas measurements. The source strength screen of 1000-times background concentration was applied to calculate groundwater AFs.

California AFs

The following table summarizes the distributions of the subslab, soil gas, and groundwater AFs for all building types after the application of source strength screens.

Statistic	Subslab (SS>50X background)	Soil Gas (SG>50X background)	Groundwater (GW>100X background)
50th percentile	0.00007	0.00004	0.00001
75th percentile	0.0004	0.0002	0.0001
90th percentile	0.002	0.0005	0.0004
95th percentile	0.005	0.0009	0.001
Number of Pairs	600	2926	213
Number of Sites	32	39	16

[1] AF percentiles calculated by the Kaplan-Meier Method.

The range of AFs observed for subslab, soil gas, and groundwater span several orders of magnitude even after screening for background sources. This divergence is most likely due to the inherent variability in media concentrations and VI processes. Additional variability is likely introduced by differences in building characteristics and localized geologic conditions.

Building Type Observations

The below table summarizes the distributions of the subslab and soil gas AFs for residential and non-residential (commercial, industrial, and schools) buildings that remain after applying the baseline and source strength screens. Groundwater AFs are not shown since available data does not have a sufficient number of paired groundwater and indoor air measurements.

Media	95th Percentile Residential Buildings	95th Percentile Non-Residential Buildings
Subslab	0.02	0.003
Soil Gas	0.0006	0.002

Observations about the analysis of building specific data from the database are:

- After filtering for source strength, insufficient residential subslab AFs are available for statistical analysis, making state-wide inference challenging.
- The three sites that yielded paired subslab measurements for residential buildings after source strength filtering are all in Southern California, making state-wide inference challenging.
- Most of the subslab sampling in California occurs at non-residential buildings. This is probably due to homeowner resistance to the invasive nature of subslab sampling and/or regulatory agencies' preference to by-pass such sampling and directly sample indoor air to evaluate impacts to human health.

- Subslab AFs for non-residential buildings should be smaller than the AFs for residential buildings as indicated by the VI conceptual model. Non-residential buildings are typically larger with higher indoor air exchange rates, thus non-residential buildings will dilute incoming vapors more than residential buildings. The statistics associated with subslab data agree with the VI conceptual model. However, while the difference between residential and non-residential AFs may be an order of magnitude, additional empirical data should be collected to verify the difference in attenuation between these two building types.

- Soil gas AFs for non-residential buildings should be smaller than for residential buildings as indicated by the VI conceptual model. Hence, the statistics associated with soil gas data do not necessarily agree with the VI conceptual model. The difference between residential and non-residential AFs is a factor of 3, and additional empirical data should be collected to verify the difference in attenuation between these two building types.

- Seventy-six percent of soil gas residential AFs were collected from one site in Southern California, making state-wide inference challenging.

Comparison of Results to Previous Studies

In the following table, the 95th percentile of AFs for subslab and soil gas are summarized for the existing empirical studies along with the results from the DTSC database. The data shown are for all building types within the studies. The results are shown to one significant digit.

Study	Subslab Attenuation Factor	Soil Gas Attenuation Factor
USEPA (2012)	0.03	0.3
Department of Defense (2015)	0.001	n/a
Ettinger and others (2018)	0.003	0.002
Derycke and others (2018)	0.04	n/a
Nawikas (2020)	0.004	n/a
DTSC (2020)	**0.005**	**0.0009**

USEPA (2012) and Department of Defense (2015) are nationwide studies. Derycke and others (2018) is a nationwide study of schools in France, but Ettinger and others (2018) and Nawikas (2020) are California-specific studies. This comparison of empirical studies indicates that the results from the DTSC study may not be consistent with the results of the nationwide studies but are consistent with the results from the available California-specific studies. Accordingly, converging lines of evidence suggest that vapor attenuation in California is different from what is observed nationwide. The differences in attenuation may be due to climatic conditions and building structures common to California.

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List of Acronyms and Abbreviations

1,1,1-TCA	1,1,1-trichloroethane
1,1-DCE	1,1-dichloroethene
AF	Attenuation Factor
Aggregate Database	combined CVOC database
BKGD	background
Cal-EPA	California Environmental Protection Agency
CARB	California Air Resources Board
CIS 1,2-DCE	cis-1,2-dichloroethene
CVOCs	chlorinated volatile organic compounds
DoD	Department of Defense
DTSC	Department of Toxic Substances Control
HVAC	heating, ventilation, and air conditioning
MS	Microsoft
OEHHA	Office of Environmental Health Hazard Assessment
PCE	tetrachloroethylene
RWQCB	Regional Water Quality Control Board
SWRCB	State Water Resources Control Board
TACs	toxic air contaminants
TCE	trichloroethylene
TRANS-1,2-DCE	trans-1,2-dichloroethene
USEPA	United States Environmental Protection Agency
VC	vinyl chloride
VI	Vapor Intrusion

1.0 INTRODUCTION

The California Environmental Protection Agency (Cal-EPA) released draft vapor intrusion (VI) guidance in early 2020 entitled *Supplemental Guidance: Screening and Evaluating Vapor Intrusion* that was based on the current technical understanding of VI and attenuation factors (AFs) based on the United States Environmental Protection Agency database (USEPA 2012a). The AFs developed by the USEPA and adopted in the *Supplemental Guidance: Screening and Evaluating Vapor Intrusion*, did not include sufficient data from sites in California. In early 2019, the Department of Toxic Substances Control (DTSC) gathered data from sites contaminated with chlorinated volatile organic compounds (CVOCs) in California to improve its knowledge and understanding of VI. The data collected from these sites was used to determine whether subslab, soil gas and groundwater AFs, that are representative of climatic conditions and types of buildings commonly found in California, could be empirically calculated. After the review of the reports from these sites, it was determined that there was sufficient data available to empirically calculate AFs for California. DTSC VI data from these sites presents the most comprehensive compilation of VI data collected to-date for CVOCs in California. The paired data associated with these sites was evaluated to develop AFs similar to the nationwide effort conducted by USEPA (2012a).

1.1 Report Purpose and Objective

The primary objective of the report is to empirically derive AFs for California using sites contaminated with CVOCs. Specifically, this study is meant to determine the following media specific AFs and provide an understanding of technical aspects of VI, as follows:

- Subslab-to-indoor air AFs for residential and non-residential buildings
- Site-specific subslab AFs for selected sites
- Soil gas-to-indoor air AFs for residential and non-residential buildings
- Site-specific soil gas AFs for selected sites
- AF relationship with soil gas sampling depths and lateral locations
- Groundwater AFs for residential and non-residential buildings
- Site-specific groundwater AFs for selected sites
- AF relationship with groundwater water sampling depths and lateral locations

1.2 Report Content

This report presents the technical information about the sites in California that have been investigated for VI. The report includes database criteria, data screening procedure, AF statistical analysis, findings, and conclusions. The report also includes the statistical analysis report developed by the Office of Environmental Health Hazard Assessment (OEHHA) to support AFs developed by DTSC. The technical information provided in this report may be useful for regulators, responsible parties, project proponents, environmental consultants, and community activists in assessing and managing VI exposure.

1.3 Report Development and Peer Review

This document was developed by staff within DTSC's Brownfield and Environmental Restoration Program. This document has been extensively peer-reviewed within Cal-EPA and other stakeholders outside Cal-EPA.

1.4 Report Organization

The report is organized into six (6) sections. Sections 1 provides introduction, purpose and objectives, background, basis for the study, and comparison of several studies conducted to-date. Section 2 provides site selection procedure, database content, database structure, and data limitations. Section 3 includes data inclusion and exclusion criteria, pairing of data, data input and quality control, third party review, and handling of data below detection limits. Section 4 provides screening methodology and analysis of the data for subslab, soil gas, and groundwater measurements. Section 5 provides findings of the analysis for subslab, soil gas and groundwater AFs. Section 6 provides the summary and conclusions. Other sections include citations, figures, and supporting appendices.

1.5 Background

VI is the migration of chemical vapors from the subsurface into buildings, and, if uncontrolled, the vapors can pose a risk to human health. The conceptual model for VI includes transport of chemical vapors from subsurface contaminant sources toward buildings, vapor entry into buildings due to foundation openings, and contaminant mixing with indoor air. Overall, vapor transport in the subsurface is controlled by contaminant partitioning, diffusion, and advection (USEPA, 2012b). Diffusion typically dominates the transport of vapors from subsurface sources toward a building or ground surface. Vapors near the building can be transported by both diffusion and advection into indoor air through foundation openings. Advection resulting from negative indoor air pressure relative to the subsurface immediately adjacent to the building typically dominates transport of vapors into indoor air (Johnson, 2005; Yao et al., 2013; USEPA, 2015a). Building heating, ventilation, and air conditioning (HVAC) operations and weather conditions cause the depressurization of buildings.

Vapor attenuation refers to the reduction in chemical concentrations that occurs during vapor migration in the subsurface, coupled with the dilution that can occur when the vapors enter a building and mix with indoor air (Johnson and Ettinger, 1991). The sum of these physical and chemical attenuation mechanisms can be quantified through the use of a VI AF, which is a non-dimensional parameter defined as the ratio of the indoor air concentration (C_{ia}) arising from VI to its associated subsurface vapor concentration (C_s), as follows:

$$AF = \frac{C_{IA}}{C_S}$$

Conceptually, the AF definition is simple. However, the process by which vapors migrate into buildings is complex and dependent on site-specific conditions. In particular, spatial and temporal variability are observed in subsurface and indoor air concentrations among buildings and within buildings (McHugh and others, 2007; Eklund and others, 2008; Luo and others, 2009; Holton and others, 2013; Pennell and others, 2016). This infers that for every site and every building at a site, a range of empirical AFs would likely be observed from a series of discrete indoor air and subsurface vapor concentrations measured at different points in space or at different times. Considering this variability, USEPA adopted a statistical approach for characterizing empirical AFs and integrated empirical AFs into their 2015 VI guidance. Empirically-derived AFs are used for the initial screening of sites to evaluate potential human exposure. The screening AFs are meant to protect public health under most building occupancy scenarios. All states adopted USEPA's empirically-derived AFs with the exception of Connecticut, Hawaii and Pennsylvania where less conservative screening approaches than USEPA's are used (Eklund and others, 2018).

1.6 Basis for the California Study

DTSC undertook this study to address some of the limitations and factors that make application of USEPA's empirical database to California challenging. Those challenges are summarized as follows:

1. USEPA's database contains very few sites from California. After filtering the database for subsurface source strength, the USEPA evaluation only included two small subslab datasets and two small soil gas datasets from California, all of which were in the San Francisco Bay Area. Furthermore, most of the data in the USEPA dataset are from New York, Colorado, Connecticut, and Montana which have colder climates than California (Ettinger and others, 2018).

2. More than 75 percent of the indoor air samples in the USEPA database were collected in residential homes with basements (Brewer and others, 2014). However, less than five percent of the single-family homes in California have basements as indicated by the United States Department of Housing and Urban Development (2017).[1]

3. AFs for commercial/industrial buildings were not generated by USEPA due to the limited amount of information on this building type in their database. Commercial and industrial buildings often have far higher indoor air exchange rates and higher

[1] The 2017 American Housing Survey shows that 4.5 percent of single-family homes have basements of the 8,212 homes surveyed in California.

ceilings which will dilute soil gas upon entry more than in a residential setting (Brenner, 2010; DTSC, 2011; Department of Defense, 2015).

4. The duration of indoor air sample collection for each subject building is not provided in the USEPA database, introducing potential source of error into the data used to derive AFs (Brewer and others, 2014).

5. Approximately 70 percent of the indoor air-to-groundwater pairs in the USEPA database were separated by more than 100 feet, reducing the reliability of AF quantification (Yao and others, 2018).

The purpose of DTSC's empirical VI study is to compile and analyze AFs collected at California sites that will be more representative of the conditions in California than the USEPA study.

1.7 Vapor Intrusion Empirical Databases

Numerous studies have been conducted to determine empirically-derived VI AFs. These studies are summarized below, and Table 1 shows their conclusions concerning AFs for screening purposes.

- <u>USEPA Nationwide Database.</u> USEPA's 2012 VI database contains data for 913 buildings in 15 states. USEPA's database contains 2,929 paired measurements, of which 35 percent are paired groundwater and indoor air measurements, 8 percent are paired exterior soil gas and indoor air measurements, 54 percent are paired subslab and indoor air measurements, and 3 percent are paired crawl space and indoor air measurements. Eighty-five percent of the data are for residential buildings and 97 percent of the chemicals in their database are CVOCs.

- <u>Nationwide Industrial Building Database.</u> The Department of Defense (DoD) (2015) compiled a VI database that initially contained paired subsurface and indoor air data for 49 industrial buildings from 12 military installations nationwide. Since 2015. the DoD has added data from an additional 30 buildings, for a current total in 2020 of 79 commercial and industrial buildings at 22 installations. The chemicals in their database are CVOCs. EPA (2012) has 1,938 indoor air results (435 indoor air results for trichloroethylene (TCE) and 378 results for tetrachloroethylene (PCE)). For comparison, the DoD industrial building database contains 7,354 indoor air results (1082 indoor air results for TCE and 923 results for PCE). Their database analysis in 2015 for the industrial buildings is generally consistent with the approach used by USEPA in 2012; since 2015, more detailed and robust statistical analysis of data from the 79 buildings has been conducted yielding greater confidence in understanding representative AFs and key VI influencing factors in commercial and industrial buildings.

- California-Specific Database. Ettinger and others (2018) created a VI database containing data for 394 buildings from 31 sites in California. Their database contains 2,180 paired measurements, of which 45 percent are paired exterior soil gas and indoor air measurements, and 55 percent are paired subslab and indoor air measurements. Fifty-three percent of the data are for residential buildings and majority of the chemicals in the database are CVOCs.

- France-Specific Database. Derycke and others (2018) compiled a VI database containing data for 51 schools from 38 towns in France. Their database contains 5,042 paired measurements of 38 separate chemicals. The numbers of paired measurements for exterior soil gas to indoor air and subslab to indoor air were not given in the study but after baseline filtering of the data, too few soil gas to indoor air pairs remained for statistical quantification. After filtering, 83 percent of the paired subslab and indoor air pairs had indoor air concentrations below the laboratory quantification limit.

- California-Specific Radon Database. Nawikas (2020) collected 220 paired subslab to indoor air measurements using radon in California. The measurements were collected from 84 commercial buildings and 70 percent of the data were collected in Los Angeles County.

Table 1.1 - Comparison of Emperically-Derived Attenuation Factors; Post-Filtering, 95th percentiles

Study	Subslab Attenuation Factor	Soil Gas Attenuation Factor
USEPA (2012)[2]	0.026	0.25[3]
Department of Defense (2015)[4]	0.001	n/a
Ettinger and others (2018)[5]	0.0026	0.0016
Derycke and others (2018)[6]	0.037	n/a
Nawikas (2020)[7]	0.004	n/a

These studies suggest that VI conditions in California might be slightly different than what is observed nationwide due to the lack of residential basements and different climatic conditions in California. Also, residential and commercial/industrial buildings

[2] Subsurface concentrations less than 50-times the indoor air background concentration were filtered from the data.
[3] An attenuation factor of 0.03 for exterior soil gas was selected by USEPA (2015) for screening purposes.
[4] The 95th percentile of their filtered data is not provided in their report but the Department of Defense selected 0.001 as a conservative screening attenuation factor for industrial building based on their analysis of the data.
[5] Subsurface concentrations less than 250 µg/m^3 were filtered from the data.
[6] No subsurface source strength filtered was performed on the data.
[7] Subsurface radon concentration less than 50-times the expected indoor air background were filtered from the data.

may behave differently in regards to vapor migration. Accordingly, the purpose of DTSC's empirical VI study is to determine the conditions of VI in California to evaluate the appropriateness of the USEPA AFs for California.

1.8 Definition of Sampling Media

Numerous lines of evidence (data) are available to evaluate exposure at VI sites. The primary lines of evidence gathered by DTSC in our empirical study are as follows:

- <u>Soil Gas Samples.</u> Subsurface vapor concentrations measured adjacent (exterior) to a building at depths of greater than five feet (DTSC, 2011; Cal-EPA, 2015). Soil gas samples can also be collected directly under a building's foundation at depth, but this occurrence is uncommon.

- <u>Subslab Samples.</u> Subsurface vapor concentrations measured directly under a building. The depth of subslab samples are typically three to four inches below the building's foundation (DTSC, 2011).

- <u>Groundwater Samples.</u> Subsurface vapor concentrations can be derived from groundwater concentrations by converting dissolved-phased concentration to a vapor concentration assuming equilibrium conditions (USEPA, 2015). Groundwater samples should be collected at the top of the shallowest-most water-bearing unit (DTSC, 2011).

- <u>Indoor Air Samples.</u> Indoor air samples can be collected with active or passive methods and can also be collected continuously.

- <u>Outdoor Air Samples.</u> Ambient air concentrations measured outside the buildings.

2.0 DATABASE DEVELOPMENT

2.1 Selection of Sites for Consideration

In May 2019, DTSC developed a preliminary list of the sites to be included in the vapor intrusion empirical database based on a temporal query of its online data management system EnviroStor. The temporal criteria, for most of the site selection, was a date of November 2011 or later, the release date of DTSC's revised VI Guidance. However, the database includes six (6) sites with data collected before November 2011. Data after November 2011, ideally, are collected consistently statewide due to the release of statewide guidance. The data collected before November 2011 was also evaluated to ensure that it meets the criteria of DTSC's VI Guidance. Additional screens, pursuant to EnviroStor, included "Confirmed Affected Media, Indoor Air, Soil Vapor, and Soil Vapor / Indoor Air." From this preliminary search, approximately 700 sites were identified statewide as possible database candidates. To focus the available State resources and minimize "selection bias," random numbers were assigned to each site and 150 sites were selected for inclusion into the database. The selection of 150 sites was based on what was perceived to be a manageable workload based on the availability of State resources. A preliminary evaluation of these 150 sites was conducted to ensure that paired data was available for inclusion in the database. DTSC concluded that only 75 of these sites had appropriately paired data. After preliminary evaluation and detailed analysis of the data associated with these 75 sites, 52 sites met the criteria developed by DTSC and therefore were included in the database. The criteria are described in detail in Section 3.0 of this report.

DTSC, being the lead oversight agency on all the sites included in the database, with the exception of two, has a high level of confidence in the data quality. Additionally, DTSC project teams working on a site, were consulted to ensure that measurements included, and data pair selection were adequate and representative of subsurface and indoor air contamination.

Numerous Regional Water Quality Control Board (RWQCB) managers were contacted concerning inclusion of their VI sites into DTSC's database. However, due to resources limitations, RWQCB staff were not available for data input except for two sites, Ford Aeronautics (Newport Beach) and Kast property (Carson). For these two sites, DTSC collaborated with the RWQCBs and their consultants to acquire these data for the database. Both Ford Aeronautics and Kast are two of the largest residential VI intrusion sites in California.

2.2 Database Structure

In California, site specific data are not electronically submitted to oversight agencies. Hence, compilation of DTSC's empirical database required physical review of assessment reports by DTSC staff. Even though the State Water Resources Control

Board (SWRCB) augmented their Geotracker database in 2018 to accept VI data, minimal data has been inputted at the time of this data evaluation. Due to the transcription of data from submitted reports to electronic format, a third-party review of all data was conducted to ensure data integrity.

The input fields for DTSC's empirical database are modeled after USEPA (2012) and the SWRCB's recent modifications to Geotracker (Cal-EPA, 2020). The number of fields within DTSC's database is smaller than those by USEPA and SWRCB. A reduced number of fields allowed for quicker database population but will reduce the magnitude of database analysis. DTSC used Microsoft (MS) Excel for the database due to its simplicity and accessibility. The database contains all fields deemed necessary for evaluation of California-specific AFs.

Upon completion of the data entry into MS Excel by DTSC staff, the spreadsheet was given to the OEHHA for statistical analysis. The data was analyzed using the R Project for Statistical Computing (R Core Team, 2019) due to its ability to readily provide statistical analysis. The description of the R software program is provided in Appendix 1.

2.3 Database Content

The database includes data from 52 sites located in 16 counties across California. The database contains 4,972 paired measurements of which 1,196 (24%) are paired subslab and indoor air measurements, 3,509 (71%) are soil gas (interior and exterior) soil gas and indoor air measurements, and 267 (5%) are groundwater to indoor air measurements. The database includes 213 buildings of which 113 (53%) are residential and 100 (47%) are commercial / industrial (non-residential). Figure 1 displays the location of the sites. DTSC database only includes data for the CVOCs PCE, TCE, 1,1-dichloroethene (1,1-DCE), cis-1,2-dichloroethene (cis 1,2-DCE), trans-1,2-dichloroethene (trans-1,2-DCE), 1,1,1-trichloroethane (1,1,1-TCA), vinyl chloride (VC)). Petroleum compounds were excluded from the database because the constituents are biodegradable, requiring more complex analysis for deriving the AFs, and are addressed by the SWRCB's Low Threat Closure Policy. Hence, the conclusion and observations from this study should not be applied to sites contaminated with petroleum constituents.

The database input fields are organized into the following categories:

- General Site Information
- Site Specific Information
- Building Information
- Subslab Sampling Information
- Soil Gas Sampling Information
- Groundwater Sampling Information
- Indoor Air Sampling Information

- Outdoor Air Sampling Information

Appendix 3 contains detailed descriptions of the input fields for each category. Table 2.1 provides a summary of site information in the database.

2.4 Data Limitations

DTSC's VI database represents a range of site conditions and types of data (Table 2.1). Very few sites have measured pairs for all media; subslab, soil gas, and groundwater. DTSC staff were provided with criteria (Section 3.0, Database Input Criteria) for determining measurement pairs but, at times, professional judgment was used in evaluation of data and deviation from the criteria where appropriate.

Additional data limitations are as follows:

1. Not all California counties are represented in the database and the most sites are located in urbanized areas.

2. USEPA sites in California were not included in in the database.

3. Only two RWQCB sites were included in the database.

4. Crawl space data was not included in the database.

5. No buildings with basements are in the database.

6. The subslab residential attenuation factors are based on measurements from three (3) sites with most of the data pairs from one site located in Southern California.

7. A significant proportion of the indoor air sampling associated with the CVOCs daughter (biodegradation) products had non-detectable concentrations.

8. Pre-indoor air sampling chemical inventories for numerous buildings were either not performed or were not available and the associated input fields in the database were left blank.

9. VI reports rarely denoted whether preferential pathways exist for a building. Hence, conclusions concerning the impact of preferential vapor migration cannot be readily inferred.

10. Most sites in the database have a "mixed" soil type, indicating the alluvial nature of California soils. Therefore, conclusions concerning vapor attenuation as a function of soil type may not be adequately evaluated.

11. Even though the depth of the soil gas samples is included in the database, the soil gas vapor depth profile associated with soil gas measurements is not available for each site.

12. Information associated with the operation of the HVAC systems were not available for many buildings, and the associated input fields in the database were left blank or denoted as “n/a.”

3.0 DATABASE INPUT CRITERIA

The intent of this study is the compilation and interpretation of VI data representative of conditions in California. As such, criteria for database input were developed to ensure data usability and consistency. The criteria, as described below, were developed using professional judgment and were based on the approach used by USEPA (2012). Only data consistent with Cal-EPA's 2003, 2012, and 2015 Active Soil Gas Advisory and DTSC's 2011 Vapor Intrusion Guidance were utilized in the database.

3.1 Data Inclusion Criteria

The following data were included in the database.

1. PCE, TCE, and their associated daughter products were included.

2. Soil gas and groundwater data were entered into the database if the corresponding sampling locations were not more than 50 feet away horizontally from the nearest edge (exterior wall) of the building. However, in some cases, at the professional judgment of DTSC staff, some of the data with longer distances were also entered.

3. If the soil gas sample was collected within a building (non-subslab), then the data was included and paired with an indoor air sample.

4. Only soil gas and groundwater data shallower than 50 feet were included in the database. At numerous sites, soil gas measurements were collected from multiple depths and were subject to numerous sampling events. However, in some cases, at the professional judgment of DTSC staff, some of the data with greater depths were also entered.

5. Indoor air measurements were only paired with subsurface data (subslab, soil gas, and groundwater) if the data were collected within three months.

6. Only outdoor air samples contemporaneous with indoor air samples were included in the database.

7. All samples with non-detectable results were included in the database along with their associated method detection and reporting limits. The database also includes analytically flagged data along with the flag type.

3.2 Data Exclusion Criteria

The following data were excluded from the database.

1. Petroleum hydrocarbons were not included.

2. Buildings with open air parking garages on the ground floor were not included.

3. Soil gas data shallower than 3 feet exterior of the building were not included in the database because of concerns associated with barometric pressure effects. The vast majority of the soil gas data in the database were collected at 5 feet or deeper.

4. Any data collected during or after vapor mitigation measures were not included the database due to concerns about disruption of contaminant equilibrium.

5. Any data collected during or after the implementation of remedial activities were excluded from the database due to concerns about disruption of contaminant equilibrium.

6. Soil gas and groundwater data deeper than 50 feet were not included. VI evaluations are typically conducted with data shallower than these depths. However, in some cases, at the professional judgment of DTSC staff, some of the data with greater depths were also entered.

3.3 Pairing of Vapor Intrusion Data

The following procedures were used for pairing indoor air measurements with subslab, soil gas, and groundwater measurements.

1. The EnviroStor reports were reviewed to determine whether the VI data met the criteria associated with spatial and temporal consistency.

2. An indoor air sample was then paired with the nearest distinct subslab, soil gas, and/or groundwater sample. For example, if a building had four indoor air samples and two exterior soil gas samples within 50 feet, four distinct pairs were formed. Each exterior soil gas sample would be paired with the two nearest indoor air samples. In some cases, however, at the professional judgement of DTSC staff, combination pairs were also included.

3. The distances from an exterior sample to the building wall was recorded in the database. As indicated by the above-mentioned criteria, most samples are within 50 feet of the building. Additionally, the distance from the exterior sample to its paired indoor air sample were also recorded. Hence, both distances were recorded in the database.

4. If multiple CVOCs were available for a single building, the data were input in the database.

3.4 Determination of Other Database Parameters

The following procedures were used for input of other data into the database.

1. Subsurface soil type was inferred from the boring logs using professional judgement or were taken from written descriptions in the text of the reports. If the information was not readily obtainable, the entry fields were left blank or annotated as “n/a.”

2. Building size was taken from the indoor air testing survey forms. If not available, building size was measured from the project site maps or estimated from Google aerial photographs.

3. Building height is rarely recorded in VI assessment reports and were, hence, estimated, where unavailable, using professional judgment.

4. A case narrative for each site was generated to document the approach for data entry. Appendix 4 contains all the case narratives.

3.5 Data Input and Quality Control

The DTSC project team reviewed the workplans and assessment reports for all 52 sites included in the database. Basic quality parameters were used to determine which data to include in the database. These parameters included site-specific information, building information, subslab, soil gas, groundwater, indoor air, and outdoor air laboratory data. DTSC internal staff were then identified to perform data entry for these sites. Almost all of the data was entered manually and then independently reviewed to ensure consistency with the criteria mentioned above.

The following activities were conducted to ensure the quality of the data:

- Overview of the site history to understand past operations, chemical use, and release history.

- Review of laboratory reports to determine if appropriate USEPA methods were used.

- Verify that sample holding times were not exceeded.

- Check chain-of-custodies for Summa canister vacuum readings at the beginning and termination of sampling events to verify the integrity of the samples.

- Review laboratory reports for leak detection compounds to determine whether samples were compromised.

- Examine laboratory reports for flagged data.

- Verify that paired measurements are spatially and temporally consistent with the criteria.

- Review building information for use, foundation type, and size.

- Verify operational status of the HVAC systems as described in the reports.

- Check boring logs to determine subsurface soil type.

- Check building surveys for indoor air sources.

3.6 Independent Review of Data

One hundred percent of data entry was verified by independent parties to ensure that all numerical values were entered correctly, and that the paired data were spatially and temporally consistent. The following is a summary of the review concerning the quality of the data.

1. Indoor Air Data. The data met the protocols in DTSC guidance. Only a few data entries were analytically flagged where data quality was deemed compromised. Eight canister samples were noted in the chain-of-custody to have zero vacuum upon receipt at the laboratory, five samples had faulty flow regulators, four samples were flagged to be compromised in the field, and two samples showed inadequate vacuum at the end of the 2-hour sampling period.

2. Subslab Data. The data met the protocols in the DTSC guidance. In five samples, leaks were detected above acceptable limits and were noted in the comment section.

3. Soil Gas Data. The data met the protocols in DTSC guidance.

4. Groundwater Data. The data met the protocols in DTSC guidance. A few samples were grab samples and were noted in the comment section.

5. Outdoor Data. The data met the protocols in DTSC guidance. Two samples showed zero vacuum at the end of the sampling period.

3.7 Evaluation of Data Below Reporting Limits

A substantial number of indoor air concentrations were reported as below reporting limits. The OEHHA recommended that the Kaplan-Meir method should be used to estimate descriptive statistics for data sets with substantial portions of data below reporting limits. The Kaplan-Meier method is a non-parametric procedure used to estimate the approximate proportion of concentrations below detection limits. The

Kaplan-Meier method assumes that data below the detection reporting limits is present in a sample, but the analytical method employed is not sufficiently sensitive in detecting those concentrations accurately (USEPA 2009).

4.0 Attenuation Factor Screening Methods and Rationale

The primary purpose of applying screening criteria was to generate a subset of the raw data pairing to calculate empirical AFs where subsurface sources were the primary contributor to CVOCs observed in residential and industrial/commercial indoor air.

4.1 Baseline Screening Criteria

Two Baseline Screens were applied to the DTSC VI Database in combination:

> **Subsurface Concentration Screen:** Exclude subsurface concentrations for subslab, soil gas, and groundwater below laboratory reporting limits.
>
> **Background Contribution Screen:** The approach used to identify indoor air data that may be biased by background contributions was to review the field notes and identify if indoor air source(s) are apparent. If indoor air sources were noted in the database upon data entry, these sites were carried forward in the analysis. An AF greater than one, if identified, were subsequently excluded from the analysis. An AF greater than one may be caused by a number of reasons, including existence of indoor air sources and influence of ambient air.

4.2 Identification Of AFs Affected By Background Indoor Air Concentrations

After the Baseline Screening described above, the DTSC VI Database was further screened for indoor air background. The objective is to exclude indoor air data below an upper-bound background concentration. A review of the available literature found no indoor air studies that could be used to estimate background indoor air concentrations in residential or industrial settings in California. Even though ambient air samples were collected for each site during the VI investigations, the number of samples and concentrations varied significantly between sites. Additionally, chemical detection limits varied significantly and were deemed not adequate for estimations of California statewide upper bound ambient air concentrations. Limitations of the site-specific ambient air data are discussed in detail in Appendix 2 (Statistical Analysis Report).

California has a comprehensive air toxics program administered by the California Air Resources Board (CARB). CARB maintains numerous real time ambient air monitoring stations throughout California and provides both monitoring site and statewide monitoring summaries for select toxic air contaminants (TACs). The DTSC VI Database only looked at the primary CVOCs. The majority of paired data in the DTSC VI Database are comprised of PCE and TCE. The CARB TAC summaries only include PCE and TCE. The CARB summaries for PCE and TCE are presented in Tables 4.1 and 4.2 for 2009 through 2018. These years coincide with the range of dates for paired data in the DTSC VI Database.

Table 4.1 – PCE Summary Statistics, 2009 – 2019, ug/m³

Year	Minimum	Median	Mean	90th percentile	Maximum
2018	0.03	0.03	0.07	0.13	0.95
2017	0.03	0.03	0.07	0.13	1.29
2016	0.03	0.03	0.12	0.27	2.58
2015	0.03	0.07	0.12	0.27	0.88
2014	0.03	0.07	0.13	0.27	1.49
2013	0.03	0.07	0.13	0.27	1.15
2012	0.03	0.07	0.13	0.27	1.42
2011	0.03	0.14	0.16	0.33	3.80
2010	0.03	0.14	0.18	0.33	1.15
2009	0.03	0.14	0.21	0.40	21.70
			Median	**0.27**	**1.36**

Table 4.2 – TCE Summary Statistics, 2009 – 2019 µg/m³

Year	Minimum	Median	Mean	90th percentile	Maximum
2018	0.03	0.03	0.06	0.05	0.32
2017	0.03	0.03	0.06	0.05	0.48
2016	0.03	0.03	0.08	0.16	0.59
2015	0.03	0.05	0.07	0.11	0.70
2014	0.03	0.05	0.10	0.11	13.97
2013	0.03	0.05	0.07	0.05	1.07
2012	0.03	0.05	0.07	0.05	1.02
2011	0.03	0.05	0.11	0.16	4.03
2010	0.03	0.05	0.08	0.11	1.18
2009	0.03	0.05	0.08	0.11	0.97
			Median	**0.11**	**0.99**

For each year, each table provides the summary statistics, including median, mean, 90th-percentile and maximum reported concentrations. To provide a true, upper-bound background ambient air concentration, the median of the maximum concentrations over the ten-year sampling period was selected for the DTSC Study. The median of the maximum concentrations of PCE, 1.36 µg/m³, was defined as the upper-bound ambient air concentration (background) to screen indoor air concentrations of PCE, TCE, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, 1,1,1-TCA, and VC. The decision to select 1.36 µg/m³ as background for all indoor air contaminants in this Study was based on professional judgement. There are no California specific studies available at this time to develop indoor air background concentrations. The selection of this background concentration provides a more reasonable approach for screening and filtering the database. All indoor air concentrations below 1.36 µg/m^3 will be excluded from the DTSC VI Database, post-baseline screening. For comparison, USEPA selected a value of 3.8 µg/m^3 for PCE.

4.3 Source Strength Screening

The data remaining following the baseline screening, described above, were further screened in order to identify AFs and data pairs that represent VI with minimal bias from background contributions. Subsurface concentrations are screened using a multiplier of the upper-bound ambient air background concentration of 1.36 µg/m^3. This approach used several multipliers of the background ambient air concentration as follows:

- Subslab. Multipliers selected for screening subslab were 10x, 50x, 100x, 500x.
- Soil Gas. Multipliers selected for soil gas were 50x, 100x and 500x.
- Groundwater. Multipliers selected for groundwater were 100x, 500x,1000x and 5000x.

4.4 Application of Screening Criteria

The DTSC VI database underwent a Baseline Screening by excluding all non-detected subsurface data. Initially, 4,972 paired measurements were available for analysis. Data were excluded if the reporting and/or detection limits were not available and the concentrations were non-detectable. This screening removed 151 pairs leaving 4,821 paired measurements for analysis. All data pairs resulting in an AF ≥1 were also excluded from the database. For data pairs with non-detected indoor air concentrations and quantifiable subsurface concentrations, the chemical-specific reporting limit was substituted for the detection limit in order to view the distribution of data.

Figure 4.1 - Box plots the AFs for sub-slab soil gas data for PCE, TCE, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, 1,1,1-TCA and VC after baseline screening.

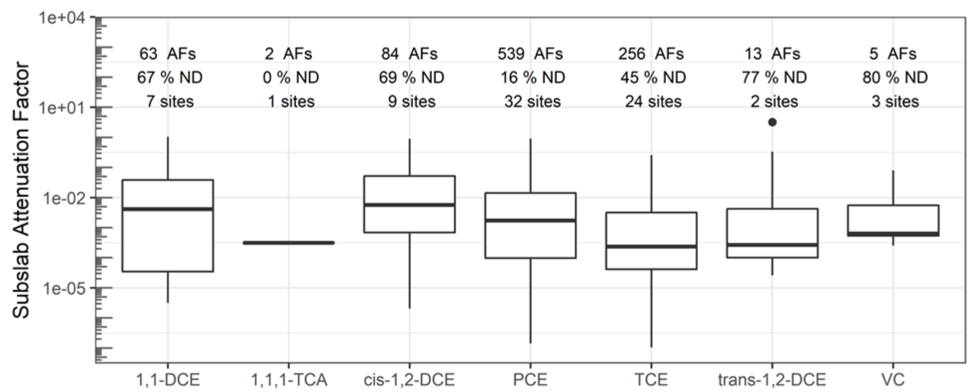


Figure 4.2 - Box Plots of the AFs for soil gas data for PCE, TCE, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, 1,1,1-TCA and VC after baseline screening.

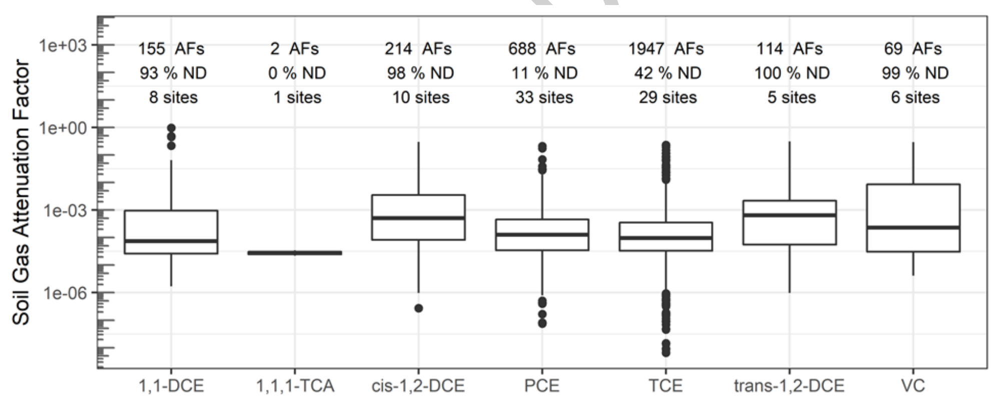
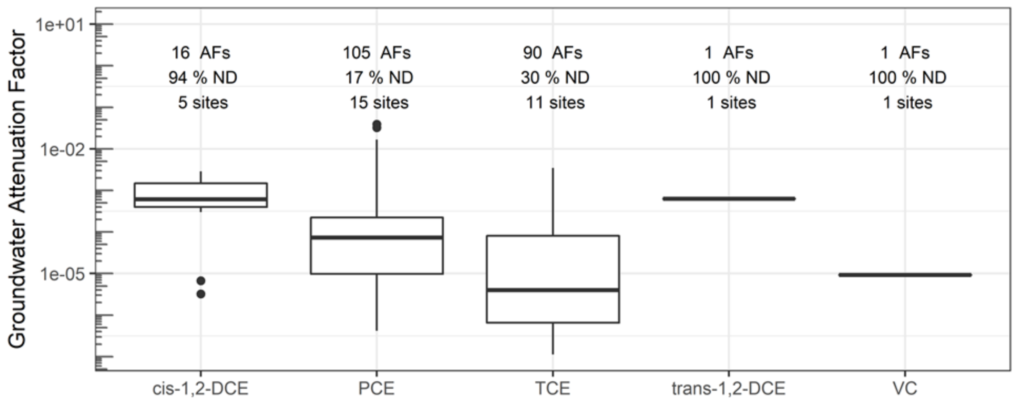


Figure 4.3 - Box Plots of the AFs for groundwater data for PCE, TCE, , cis-1,2-DCE, trans-1,2-DCE and VC after baseline screening.



As shown on the above figures, only PCE and TCE have low frequencies of non-detected concentrations in indoor air. The daughter products, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE and VC, have between 70- and 100-percent of the data as non-detects. Consequently, the Kaplan-Meier statistical method can't be used to estimate the summary statistics for these daughter products (USEPA, 2009).

However, as can be seen from the above Box Plots, there is reasonable agreement between the data distributions for PCE, TCE, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE and VC. Consequently, it was decided to include the data for PCE, TCE, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, VC and 1,1,1-TCA into a combined CVOC database (Aggregate Database). Baseline Screening was conducted on the Aggregate Database, again excluding all data pairs where the subsurface concentrations were non-detected and the AF ≥1. The Box Plots for the aggregate database following baseline screening are presented in Figures 4.4, 4.6 and 4.8 for the subslab soil gas, soil gas and groundwater data sets, respectively.

All aggregate indoor air concentrations were further screened using the upper-bound background air concentrations of 1.36 µg/m^3 and excluding all indoor air concentrations below this background value.

Next, the Aggregate CVOC Data, following the baseline screen described above, were further evaluated to identify appropriately high subsurface vapor concentrations with minimal bias from background contributions. Source strength screening was conducted by selecting subsurface concentrations that exceed background by a specific multiplicative factor, such as 10-, 50-, 100-, 500- or 1,000-times the identified background air concentration of CVOCs. In this case, 1.36 µg/m^3.

4.5 Subslab Soil Gas Data

Figures 4.4 and 4.5 present the Box Plots and Density Plots for the subslab soil gas AFs following various database screens.

Figure 4.4 – Aggregate Sub-Slab AF Box Plots

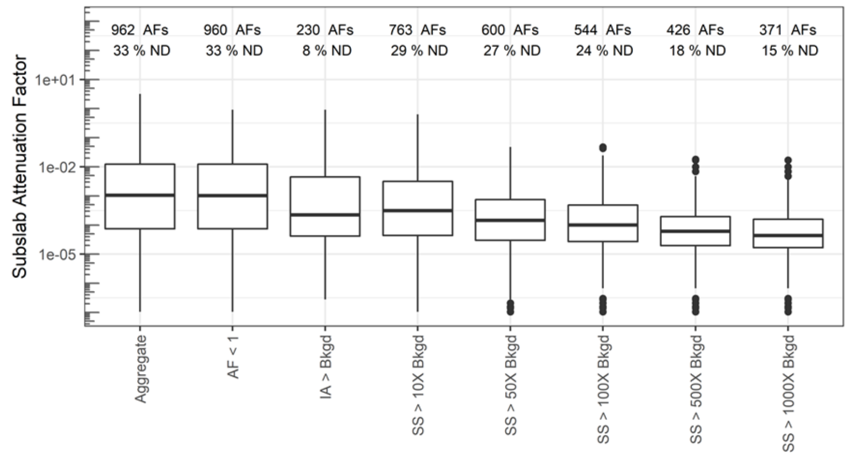
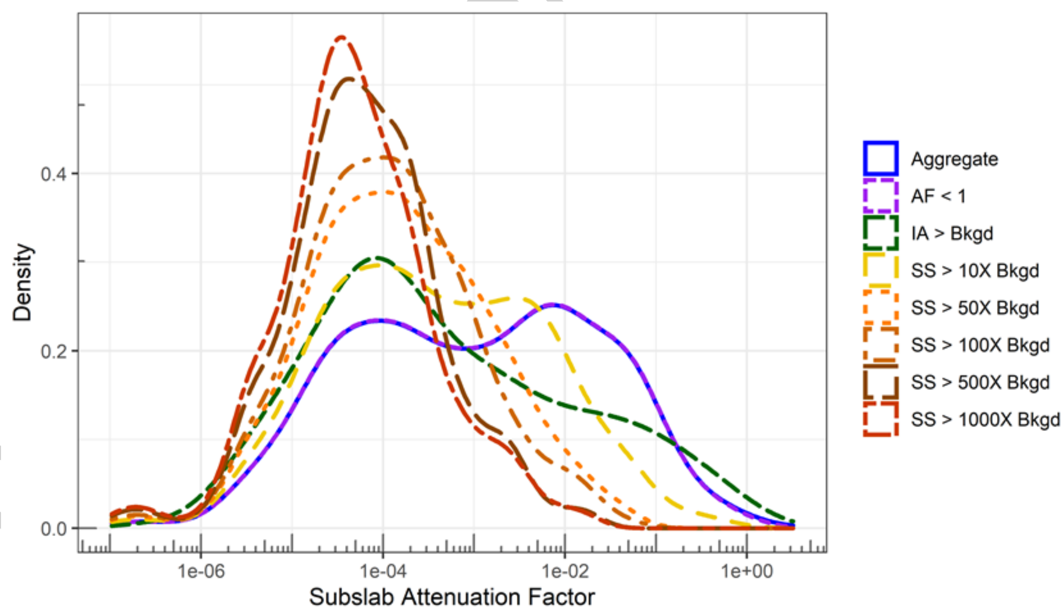


Figure 4.5 - Density Plots of Subslab Soil Gas Data Following Various Database Screens



From Figure 4.5, following the Baseline Screening process, the data distribution appears bi-modal (combined blue and purple lines), indicating the potential influence of background sources. Excluding indoor air less than background improves the distribution, but it still appears bi-modal. Excluding indoor air below background significantly reduces the number of data pairs from 960 down to 230 (Figure 4.4), likely eliminating data pairs attributable to VI. From Figure 4.5, the source strength screens appear to reduce the bimodality of the database, while still maintaining more AF data pairs (Figure 4.5). A source strength screen of 50-times background was selected as the most appropriate screening criterion for reducing the potential influence of background sources while maintaining a larger number of AF data pairs. Consequently, the source strength screen of 50-times background will be carried forward in this report to evaluate subslab soil gas, as described in Section 5.0.

The above approach and rationale for selecting the source strength screen multiplier was based on the approach used in the USEPA VI Study (USEPA 2012a). EPA also selected a subslab soil gas source strength multiplier of 50-times background.

Table 4-3 summarizes the descriptive statistics for the subslab AFs after the application of various database screens.

Table 4.3 - Descriptive Statistics of Subslab AFs Following Various Database Screens

Database Screen	Number of Subslab Data Pairs	Subslab AF percentiles[1]			
		95th	90th	75th	50th
Aggregate[2]	962	0.06	0.023158	0.003692	0.000167
AF < 1	960	0.06	0.023158	0.003692	0.000167
IA > Bkgd	230	0.182051	0.06	0.002522	0.000167
SS > 10X Bkgd	763	0.024706	0.009412	0.001366	0.000103
SS > 50X Bkgd	600	0.00481	0.002332	0.000379	6.67E-05
SS > 100X Bkgd	544	0.003146	0.001472	0.000262	6.04E-05
SS > 500X Bkgd	426	0.0018	0.000674	0.000167	4.42E-05
SS > 1000X Bkgd	371	0.001692	0.000598	0.000155	3.92E-05

[1] AF percentiles calculated by the Kaplan-Meier Method.

[2] Aggregate CVOC Database, baseline conditions with no screening

Selected source strength screen

4.6 Soil Gas Data

Figures 4.6 and 4.7 present the Box Plots and Density Plots for the soil gas AFs following various database screens.

Figure 4.6 - Aggregate Soil Gas AF Box Plots

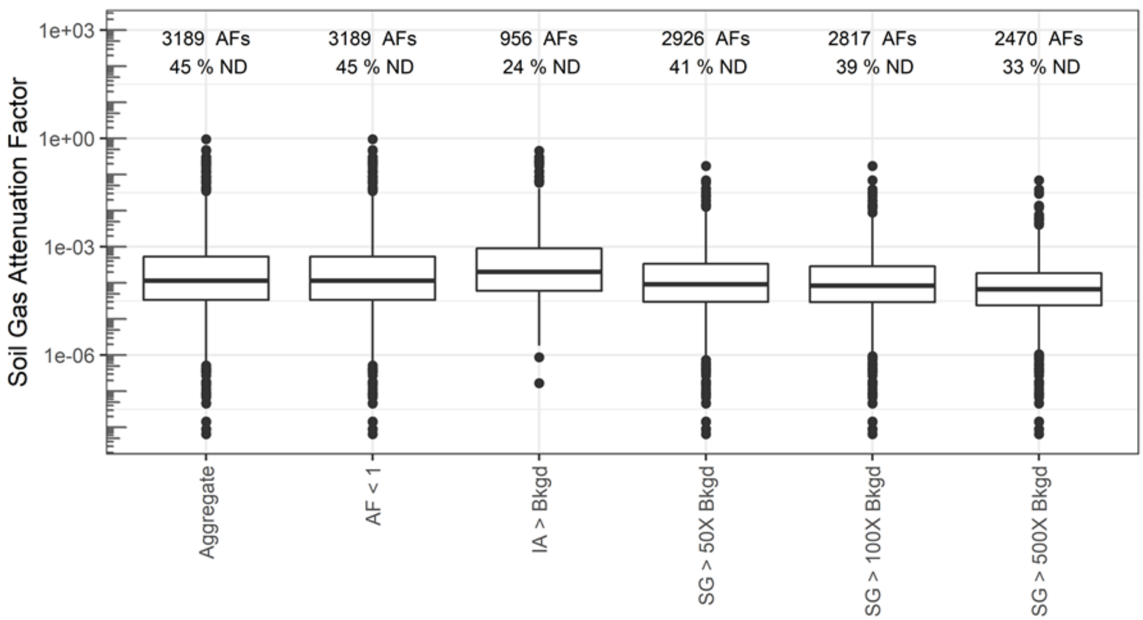
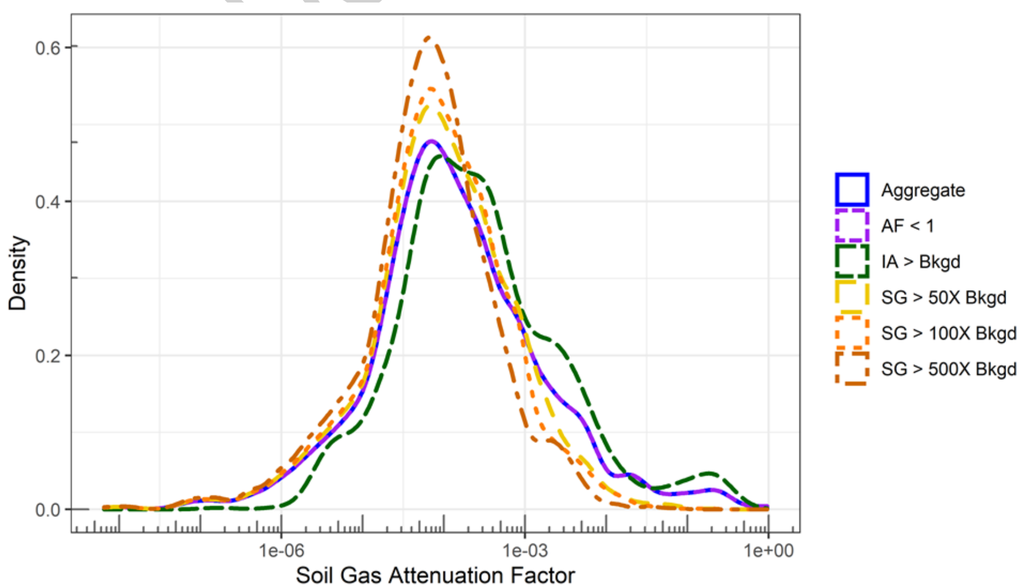


Figure 4.7 - Density Plots of Subslab Soil Gas Data Following Various Database Screens



From Figure 4.7, following the Baseline Screening process, the soil gas data distribution appears multi-modal (combined blue and purple lines), indicating the potential influence of background sources. Excluding indoor air concentrations below background still results in a multi-modal distribution and significantly reduces the number of data pairs from 3,189 down to 956 (Figure 4-6). From Figures 4-6 and 4-7, all the source strength screens result in an improved data distribution while maintaining the number of data pairs for estimation of soil gas AFs. A source strength screen of 50-times background was selected as the most appropriate screening criterion for reducing the potential influence of background sources while maintaining a larger number of AF data pairs. Consequently, the source strength screen of 50-times background will be carried forward in this report to evaluate soil gas, as described in Section 5.0.

The above approach and rationale for selecting the source strength screen multiplier was based on the approach used in the USEPA VI Study (USEPA 2012a). USEPA also selected a soil gas source strength multiplier of 50-times background.

Table 4-4 summarizes the descriptive statistics for soil gas AFs after the application of various database screens.

Table 4.4 - Descriptive Statistics of Soil Gas AFs Following Various Database Screens

Database Screen	Number of Soil Gas Data Pairs	Soil Gas AF Percentiles[1]			
		95th	90th	75th	50th
Aggregate[2]	3189	0.00104	0.000489	0.000157	4.43E-05
AF < 1	3189	0.00104	0.000489	0.000157	4.43E-05
IA > Bkgd	956	0.002623	0.001109	0.00038	0.000124
SG > 50X Bkgd	2926	0.000865	0.000461	0.000153	4.34E-05
SG > 100X Bkgd	2817	0.000833	0.000455	0.00015	4.33E-05
SG > 500X Bkgd	2470	0.000732	0.000411	0.000141	4.19E-05

[1] AF percentiles calculated by the Kaplan-Meier Method.

[2] Aggregate CVOC Database, baseline conditions with no screening

Selected source strength screen

4.7 Groundwater Data

Figures 4.8 and 4.9 present the Box Plots and Density Plots for the groundwater AFs following various database screens.

Figure 4.8 - Aggregate Groundwater AF Box Plots

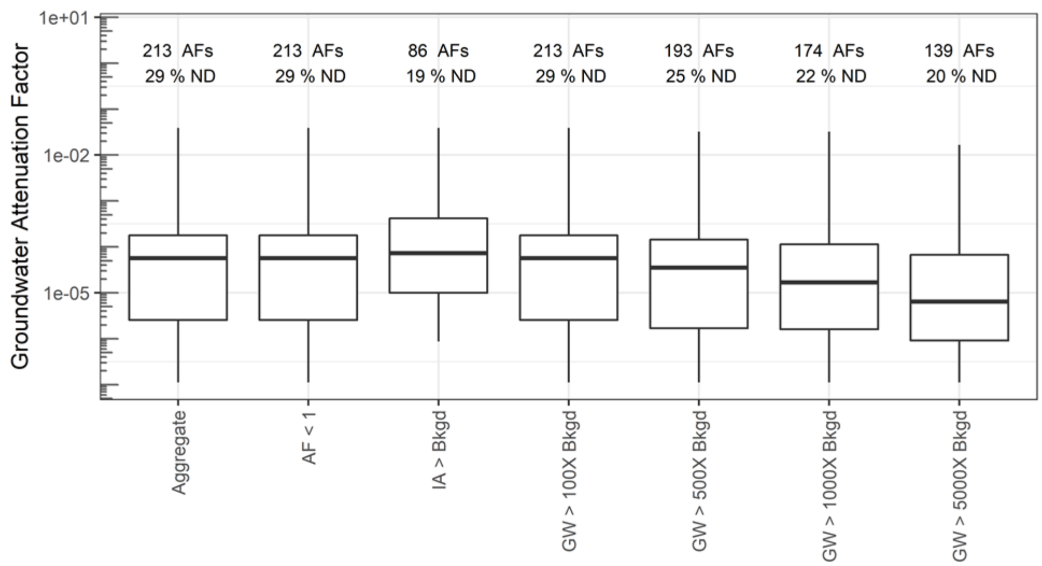
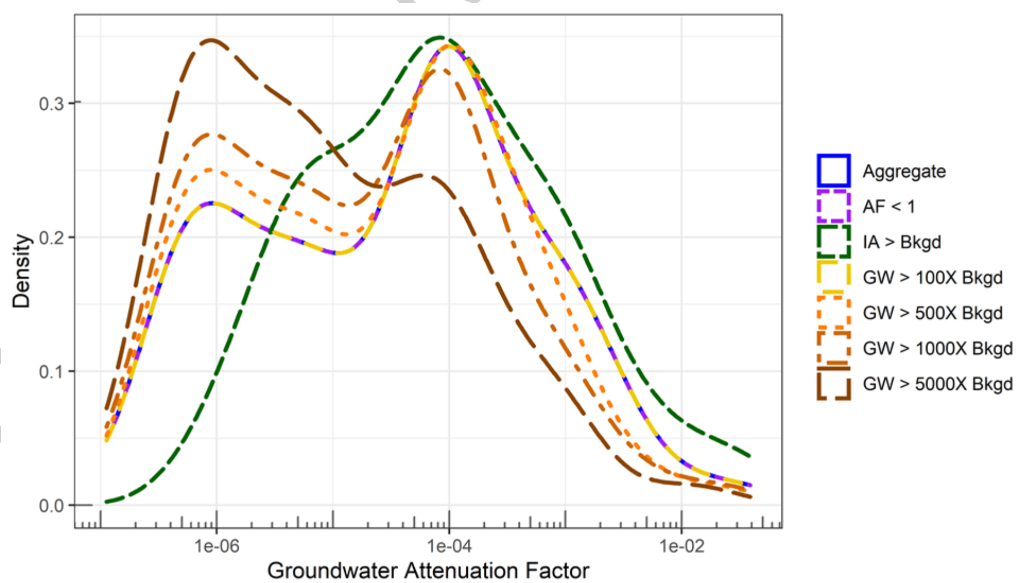


Figure 4.9 - Groundwater AF Density Plots



From Figure 4.9, following the Baseline Screening process, the groundwater AF data distribution appears multi-modal (combined blue and purple lines), indicating the potential influence of background sources. While the source strength screens appear to somewhat improve the distributions, all the distributions remain multi-modal in nature. Using the same reasoning applied to both the subslab soil gas and soil gas data, a source strength screening criterion of 100-times background was selected for the groundwater source strength screen multiplier. As shown in Figure 4.9, the data distributions for application of 100-, 500- and 1000-times background, resulted in almost identical density plots. Further, as shown in Table 4-5, the 95th percentile groundwater AF, 0.001, was identical for all three multipliers. A source strength multiplier of 100-times background was chosen to maintain a larger number of data pairs. Consequently, the source strength screen of 100-times background will be carried forward in this report to evaluate groundwater data, as described in Section 5.0.

The above approach and rationale for selecting the source strength screen multiplier was based on the approach used in the USEPA VI Study (USEPA 2012a). USEPA selected a groundwater source strength multiplier of 1000-times background.

Table 4-5 summarizes the descriptive statistics of groundwater AFs after the application of various database screens.

Table 4.5 - Descriptive Statistics of Groundwater AFs Following Various Database Screens

Database Screen	Number of Groundwater Data Pairs	Groundwater AF percentiles[1]			
		95th	90th	75th	50th
Aggregate[2]	213	0.00101	0.000362	0.000114	1.33E-05
AF < 1	213	0.00101	0.000362	0.000114	1.33E-05
IA > Bkgd	86	0.006677	0.00101	0.000224	5.72E-05
GW > 100X Bkgd	213	0.00101	0.000362	0.000114	1.33E-05
GW > 500X Bkgd	193	0.00101	0.00035	0.000114	1.10E-05
GW > 1000X Bkgd	174	0.00101	0.000224	7.47E-05	9.58E-06
GW > 1000X Bkgd	139	0.00101	0.000185	5.72E-05	3.82E-06

[1] AF percentiles calculated by the Kaplan-Meier Method.

[2] Aggregate CVOC Database, baseline conditions with no screening

Selected source strength screen

The lack of potential groundwater pairs in DTSC's database is attributable to the data selection criteria. For groundwater data to be selected for the database, the groundwater monitoring wells had to be within 50 feet of the building and groundwater elevations had to be shallower than 50 feet, which excludes available data. Additionally, the spatial density of groundwater wells is usually less than that of soil gas probes.

After the application of the screens mentioned in the preceding section, the remaining data was used to estimate sub-slab, soil gas, and groundwater AFs. After the data was appropriately screened, the ratio of concentration of chemical in indoor air and the corresponding sub-surface vapor and groundwater concentrations were used to calculate the AFs.

5.0 Discussion of Findings

As discussed in section 4.0, the subslab, soil gas, and groundwater data were screened with various criteria to minimize the influence of background sources to calculate AFs that most closely represent the VI process. DTSC evaluated descriptive statistics associated with the sub-slab, soil gas and groundwater AFs. The subsurface screens used for subslab, soil gas, and ground water concentrations were 50-, 50-, and 100-times the background concentration, respectively to calculate AFs. The indoor air data reported below detection limits were incorporated in the analysis using Kaplan-Meier method. This section provides key findings including descriptive statistics and AFs. The key findings in this section are organized as follows:

- AFs for subslab, soil gas, and groundwater were calculated
- Subslab soil gas and groundwater AFs for sites with greater than 15, 40, and 7 pairs respectively were calculated
- AFs were calculated for residential and non-residential buildings
- AFs associated with soil gas and groundwater depths
- AFs associated with lateral distance from the buildings

5.1 Subslab AFs

The 95^{th}, 90^{th}, 75^{th}, and 50^{th} percentile subslab AFs for the combined data are 0.00481, 0.0023, 0.00038, and 0.000067, respectively. The AFs were calculated using 600 pairs from 32 sites across California after the application of baseline and source strength screen of 50x background concentration. Table 5.1 summaries descriptive Statistics (50^{th}, 75^{th}, 90^{th}, and 95^{th} percentile) for the subslab AFs.

Table 5.1 - Descriptive Statistics (50th, 75th, 90th, and 95th percentiles) for the subslab AFs

Number of Sublab Data Pairs	Subslab AF percentiles[1]			
	95^{th}	90^{th}	75^{th}	50^{th}
600	0.00481	0.00233	0.000379	6.67E-05

[1] AF percentiles calculated by the Kaplan-Meier Method.

5.2 Site-Specific Subslab AFs

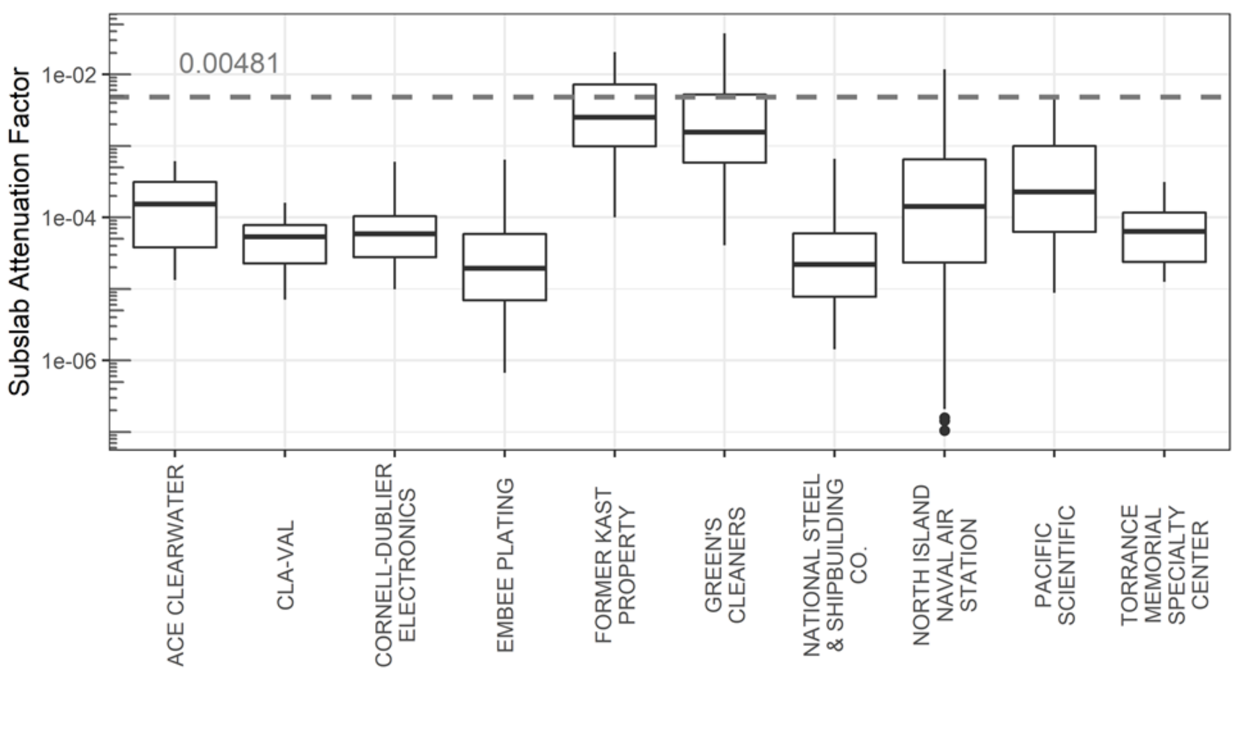
An examination of subslab AFs for selected sites was performed to determine how the AFs vary from each other. The sites with greater than 15 pairs were selected. Table 5.2 summaries descriptive statistics (50^{th}, 75^{th}, 90^{th}, and 95^{th} percentiles) and Figure 5.1 shows box plots summarizing subslab AFs for these sites.

Table 5.2 - Descriptive Statistics (50th, 75th, 90th, and 95th percentiles) for sites with greater than 15 pairs

Site Name	Number of Subslab Data Pairs	Subslab AF percentiles[1]			
		50th	75th	90th	95th
ACE CLEARWATER	18	0.000155	0.000313	0.000600	0.000612
CLA-VAL	34	0.000052	0.000079	0.000157	0.000157
CORNELL-DUBLIER ELECTRONICS	26	0.000058	0.000108	0.000253	0.000506
EMBEE PLATING	27	0.000007	0.000021	0.000056	0.000061
FORMER KAST PROPERTY	38	0.002474	0.007333	0.010000	0.019444
GREEN'S CLEANERS	49	0.001399	0.002523	0.006957	0.010031
NATIONAL STEEL & SHIPBUILDING CO.	20	0.000008	0.000031	0.000074	0.000250
NORTH ISLAND NAVAL AIR STATION	168	0.000030	0.000118	0.000389	0.000750
PACIFIC SCIENTIFIC	32	0.000220	0.000950	0.003438	0.003875
TORRANCE MEMORIAL SPECIALTY CENTER	21	0.000051	0.000091	0.000195	0.000297

[1] AF percentiles calculated by the Kaplan-Meier Method.

Figure 5.1 - Box Plots of the AFs for sites with greater than 15 pairs



As shown in Table 5.2, 95th percentile of individual sites varies one to three orders of magnitude from combined subslab AF of 0.00481. All sites, with the exception of two, have an AF lower than 0.00481.

The 90th percentile also varies one to two orders of magnitude from the combined 90th percentile subslab AF. One site has higher AF than 90th percentile of the combined subslab AF of 0.00233.

The median AFs for these sites have one to two orders of magnitude difference from 50th percentile combined subslab AF of 0.000066.

5.3 Residential Versus Non-Residential Subslab AFs

The residential subslab AFs are based on sites that are defined as residential which include single family homes and apartment complexes. Most of the indoor air samples are collected in bedrooms, living rooms, bathrooms, and kitchens. The non-residential AFs were based on sites that are defined as industrial, commercial, or schools end-use. Most non-residential buildings are warehouses, shopping plazas, storage spaces, manufacturing facilities, and classrooms.

The findings of the analysis are provided in Table 5.3. Figure 5.2 is a box plot of the AFs. The 95th percentile for residential buildings, based on 42 pairs from three (3) sites is 0.0180. The 95th percentile AFs for residential and non-residential buildings vary by one order of magnitude.

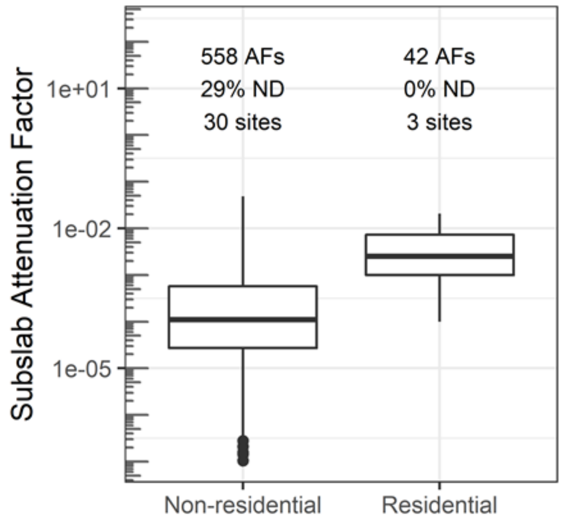
The non-residential AF, based on 558 pairs from 30 sites in California, is 0.0031. For non-residential buildings, the 90th and 75th percentiles have one order of magnitude difference and 75th and 50th are in the same order of magnitude range.

Table 5.3 - Descriptive Statistics (50th, 75th, 90th, and 95th percentiles) for residential and non-residential sites

Building Use	Number of Subslab Data Pairs	No of Sites	%NDs	Subslab AF percentiles[1]			
				95th	90th	75th	50th
Non-residential	558	30	29	0.0031	0.0012	0.0002	0.0001
Residential	42	3	0	0.0180	0.0100	0.0073	0.0025

[1] AF percentiles calculated by the Kaplan-Meier Method.

Figure 5.2- Box Plots of the AFs for residential and non-residential sites



5.4 Soil Gas AFs

As shown in Table 5.4, the 95th, 90th, 75th, and 50th percentile soil gas AFs are 0.00087, 0.0005, 0.0002, and 0.0000434, respectively. The soil gas AFs were calculated using 2,926 pairs from 39 sites across California after the application of baseline and source strength screen of 50-times the background concentration.

Table 5.4 - Descriptive Statistics (50th, 75th, 90th, and 95th percentile) for the soil gas AFs.

Number of Soil Gas Data Pairs	Soil Gas AF percentiles[1]			
	95th	90th	75th	50th
2926	0.000865	0.000461	0.000153	4.34E-05

[1] AF percentiles calculated by the Kaplan-Meier Method.

5.5 Site-Specific Soil Gas AFs

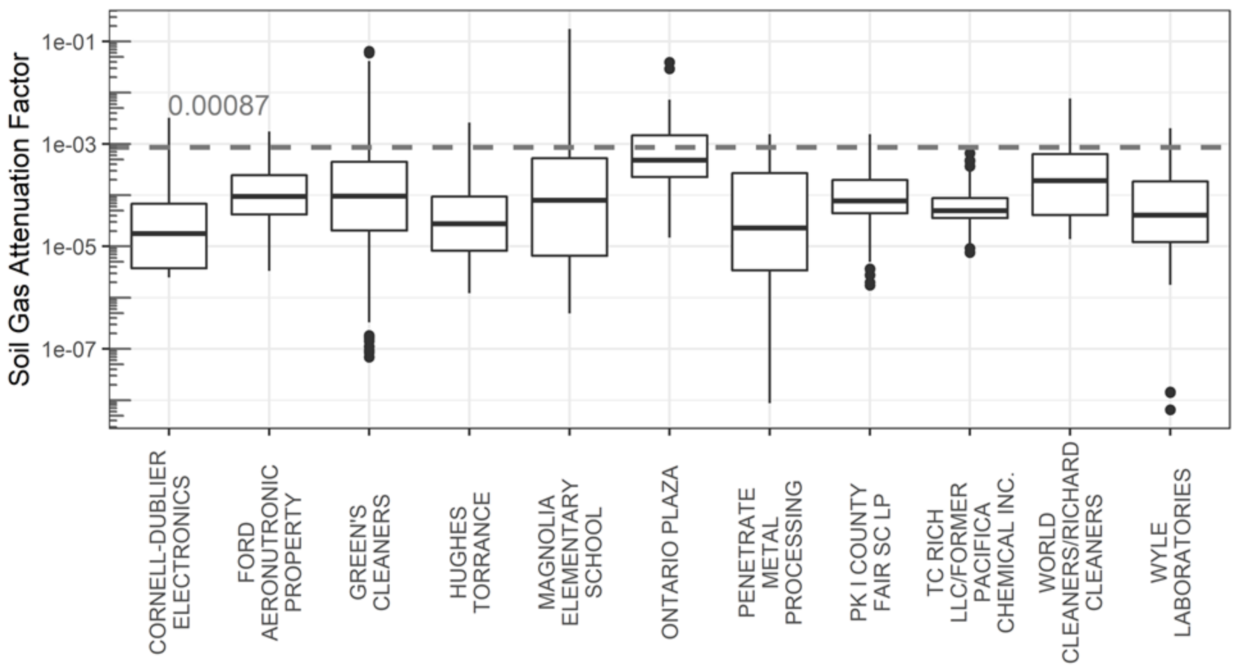
An examination of soil gas AFs for selected sites was performed to determine how the AFs vary from each other. The sites with greater than 40 pairs were selected. Table 5.5 summarizes descriptive Statistics (50th, 75th, 90th, and 95th percentiles) and Figure 5.3 shows box plots summarizing subslab AFs for these sites.

Table 5.5 - Descriptive Statistics (50th, 75th, 90th, and 95th percentiles) for sites with greater than 40 pairs

Site Name	Number of Soil Gas Data Pairs	Soil Gas AF percentiles[1]			
		50th	75th	90th	95th
CORNELL-DUBLIER ELECTRONICS	45	0.0000178	0.0000683	0.0004562	0.0005500
FORD AERONUTRONIC PROPERTY	1133	0.0000575	0.0001383	0.0003183	0.0004740
GREEN'S CLEANERS	721	0.0000029	0.0001031	0.0003571	0.0005944
HUGHES TORRANCE	45	0.0000278	0.0000936	0.0004769	0.0010690
MAGNOLIA ELEMENTARY SCHOOL	88	0.0000300	0.0001737	0.0007258	0.0021176
ONTARIO PLAZA	70	0.0004643	0.0015072	0.0031325	0.0054545
PENETRATE METAL PROCESSING	153	0.0000015	0.0000158	0.0000429	0.0000819
PK I COUNTY FAIR SC LP	63	0.0000416	0.0001074	0.0001957	0.0002104
TC RICH LLC/FORMER PACIFICA CHEMICAL INC.	53	0.0000486	0.0000700	0.0001833	0.0002877
WORLD CLEANERS/RICHARD CLEANERS	42	0.0001667	0.0006290	0.0027778	0.0036923
WYLE LABORATORIES	103	0.0000224	0.0001234	0.0004643	0.0011622

[1] AF percentiles calculated by the Kaplan-Meier Method.

Figure 5.3 - Box Plots of the AFs for sites with greater than 40 pairs



As shown in Table 5.4, the 95th percentile of individual sites varies one to two orders of magnitude from the combined soil gas AF of 0.00087. The 90th and 50th percentile AFs both vary an order of magnitude from combined AFs.

5.6 Residential Versus Non-Residential Soil Gas AFs

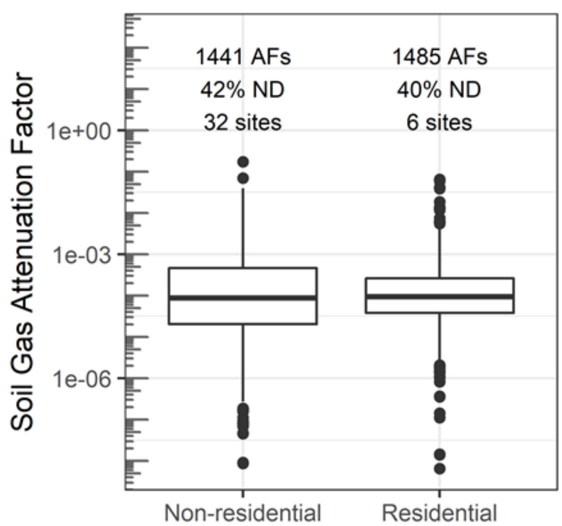
The findings of the analysis for residential and non-residential buildings are provided in Table 5.6. Figure 5.4 shows the box plots of residential and non-residential AFs. The non-residential 95th percentile AF, based on 1,441 pairs from 32 sites in California, is 0.0016. The residential 95th percentile AF, based on 1,485 pairs from 6 sites in California, is 0.00057. The 95th percentile of AFs for residential and non-residential buildings vary by a factor of three. The 90th, 75th, and 50th percentile of non-residential and residential AFs are numerical similar.

Table 5.6 - Descriptive Statistics (50th, 75th, 90th, and 95th percentiles) for residential and non-residential sites

Building Use	Number of Soil Gas Data Pairs	No of Sites	%NDs	Soil Gas AF percentiles[1]			
				95th	90th	75th	50th
Non-residential	1441	32	42	0.001629	0.000643	0.000161	3.33E-05
Residential	1485	6	40	0.000571	0.00036	0.000141	5.21E-05

[1] AF percentiles calculated by the Kaplan-Meier Method.

Figure 5.4 - Box Plots of the AFs for residential and non-residential sites



The descriptive statistics associated with residential AFs are largely based on the data (1,133 pairs out of total 1,485 pairs) collected at Ford Aeronautics site with the 95th percentile AF of 0.000474. The descriptive statistics associated with non-residential AFs are based on data (721 pairs out of total 1,441 pairs) collected at Green's cleaners' site with the 95th percentile AF of 0.000594.

5.7 AF Relationship with Soil Gas Sampling Depths

The AF was also calculated based on the depth of soil gas sample collection to evaluate whether AFs are consistent with conceptual VI model. Of the 39 sites in the database with soil gas samples, 14 have soil gas samples collected at multiple depths below ground surface.

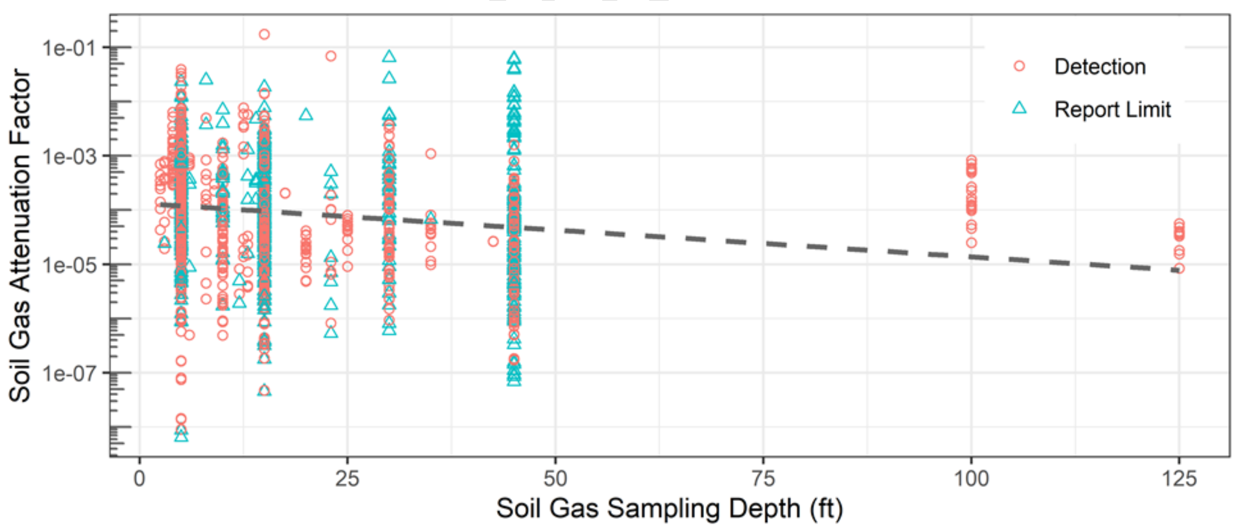
Table 5.7 provides the summary of descriptive statistics (50^{th}, 75^{th}, 90^{th}, and 95^{th} percentiles) at various depth intervals. As expected, the AF shows an inverse relationship with depth for the three ranges. Note, however, that AF with sampling depth greater than 20 ft has a high percentage of concentrations below the detection limits so the estimation of AFs has high uncertainties. The results of statistical test of significance show that the differences of AFs between depth ranges are statistically different but only vary by a factor of 2 (See Appendix 2). Figure 5.5 plotted density of the AFs for three groups.

Table 5.7- Descriptive Statistics (50^{th}, 75^{th}, 90^{th}, and 95^{th} percentiles) at depth intervals for soil gas

Depth Range	Number of Soil Gas Data Pairs	No of Sites	%NDs	Soil Gas AF percentiles[1]			
				95^{th}	90^{th}	75^{th}	50^{th}
<= 10 ft	1334	32	32	0.001222	0.000655	0.000286	1.00E-04
10 - 20 ft	1036	28	42	0.000582	0.000244	0.00008	3.81E-05
> 20 ft	538	11	64	0.000433	0.000159	4.44E-05	3.30E-06

[1] AF percentiles calculated by the Kaplan-Meier Method.

Figure 5.5 - Scatter plot for three depth ranges with trend line



5.8 AF Relationship with Lateral Distances

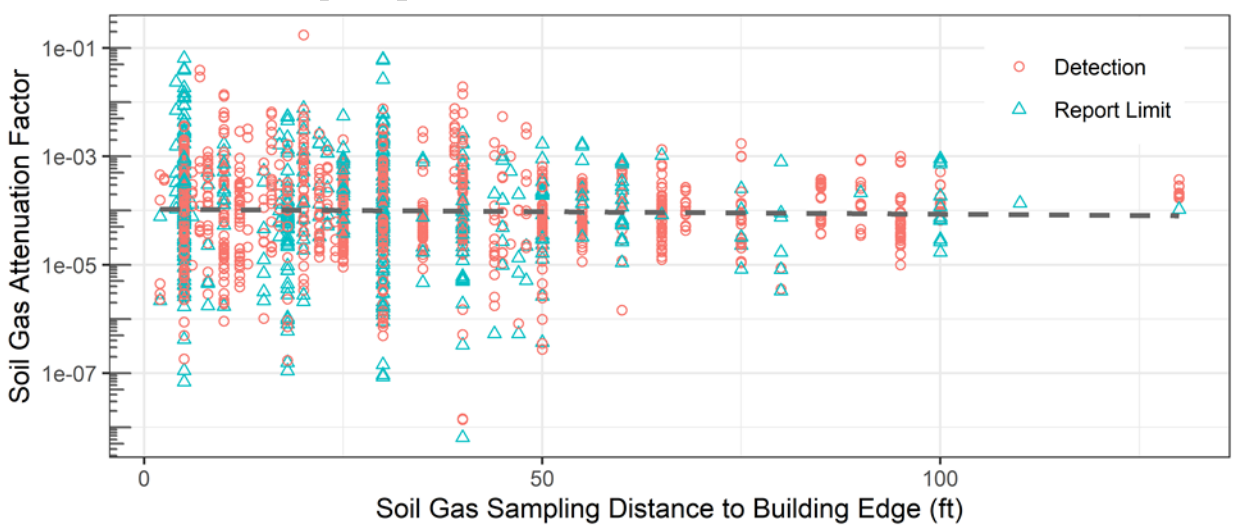
The AFs were also calculated based on the lateral distances of the soil gas sample from the edge of the building to determine whether a relationship can be discerned. Almost all the sites (with the exception of two) have a lateral distance of 50 feet or less consistent with the criteria previously defined. Thus, approximately 80% of the pairs were located less than or equal to the distance of 50 feet. Table 5.8 provides summary of descriptive Statistics (50th, 75th, 90th, and 95th percentiles) at various distance ranges. As indicated in the Table 5.8, AFs are in the same numerical range for all the distance ranges shown. Additionally, correlation between the AF and the distances was also examined. The results indicated that there is minimal correlation between the AF values and the distances.

Table 5.8 - Descriptive Statistics (50th, 75th, 90th, and 95th percentiles) at four distance ranges

Distance Range	Number of Soil Gas Data Pairs	No of Sites	%NDs	Soil Gas AF percentiles[1]			
				95th	90th	75th	50th
<= 10 ft	498	19	44	0.001276	0.000726	0.000232	3.26E-05
10 - 25 ft	526	15	35	0.001018	0.000587	0.00025	6.75E-05
25 - 50 ft	834	16	45	0.000802	0.000451	0.000123	4.04E-05
> 50 ft	485	2	41	0.000398	0.000302	0.00014	5.56E-05

[1] AF percentiles calculated by the Kaplan-Meier Method.

Figure 5.6- Scatter plot for distance ranges



5.9 Groundwater AFs

The 95th, 90th, 75th, and 50th percentiles groundwater AFs for the combined data are 0.001, 0.0004, 0.0001, 0.0001, 0.00001, respectively. The AF was calculated using 213 pairs from 16 sites across California after the application of baseline and source strength screen of 100-times the background concentration. Table 5.9 summarizes descriptive Statistics (50th, 75th, 90th, and 95th percentile) for the groundwater AFs.

Table 5.9 - Descriptive Statistics (50th, 75th, 90th, and 95th percentiles) for groundwater AFs.

Number of Groundwater Data Pairs	Groundwater AF percentiles[1]			
	95th	90th	75th	50th
213	0.00101	0.00035	0.000114	1.10E-05

[1] AF percentiles calculated by the Kaplan-Meier Method.

5.10 Site-Specific Groundwater AFs

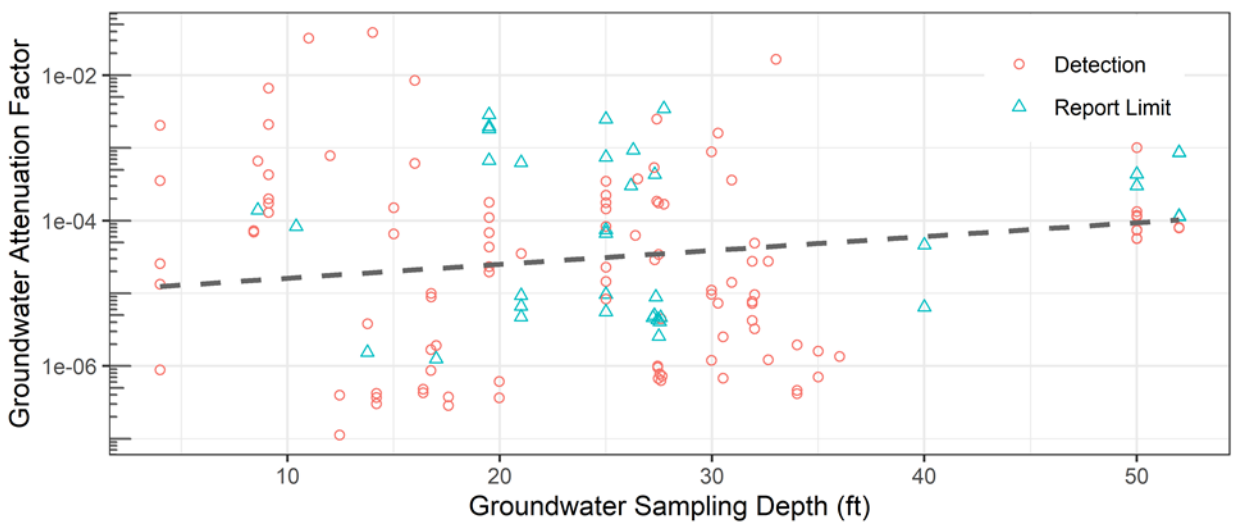
An examination of groundwater AFs for selected sites was performed to determine how the AFs vary from each other. The sites with greater than seven (7) pairs were selected. Table 5.10 provides the summary of descriptive statistics for groundwater AFs (50th, 75th, 90th, and 95th percentiles). The 95th percentile AFs vary one to three orders of magnitude from the combined 95th percentile AF. The 90th percentile and median vary one to two orders of magnitude from the combined 90th percentile AF. Figure 5.10 shows the scatter plot for groundwater AFs for these sites.

Table 5.10 - Descriptive Statistics (50th, 75th, 90th, and 95th percentiles) for sites with greater than 7 pairs

Site Name	Number of Groundwater Data Pairs	Groundwater AF percentiles[1]			
		50th	75th	90th	95th
ACE CLEARWATER	26	0.0000025	0.0000141	0.0003618	0.0008828
CARROLL SHELBY ENTERPRISES	26	0.0000010	0.0000625	0.0001852	0.0005357
FORMER QUALITY DRY CLEANING	9	0.0000682	0.0001786	0.0003750	0.0003750
TC RICH LLC/FORMER PACIFICA CHEMICAL INC.	39	0.0001142	0.0001193	0.0005510	0.0010100
WYLE LABORATORIES	41	0.0000004	0.0000009	0.0000038	0.0000089

[1] AF percentiles calculated by the Kaplan-Meier Method.

Figure 5.7- Scatter plot of the AFs sites with greater than 7 pairs with trend line



5.11 AF Relationship with Depths of Groundwater Samples

The AF was also calculated based on the depth of the groundwater sample to evaluate whether AFs are consistent with conceptual VI model. Table 5.11 shows AFs at various depth ranges.

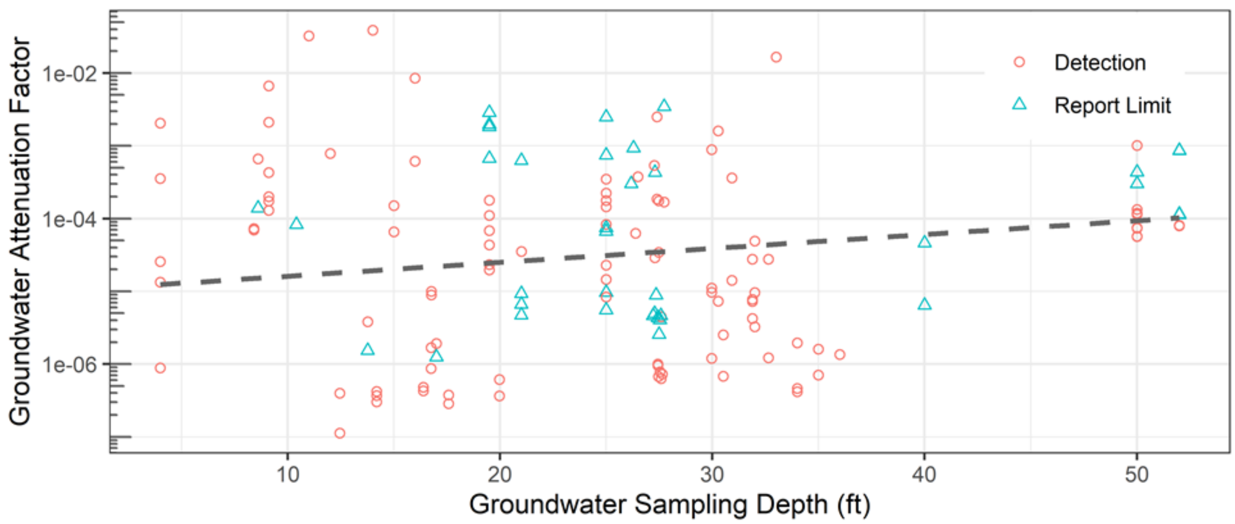
Table 5.11 - Descriptive Statistics (50th, 75th, 90th, and 95th percentile) at four depth ranges

Depth Range	Groundwater Data Pairs	No of Sites	%NDs	Groundwater AF percentiles[1]			
				95th	90th	70th	50th
<= 15 ft	32	5	12	0.032407	0.00211	0.000357	6.60E-05
15 - 25 ft	57	6	35	0.00035	0.000224	8.33E-05	8.90E-06
25 - 40 ft	59	6	22	0.001608	0.000375	0.000029	3.20E-06
> 40 ft	50	2	30	0.00101	0.000133	0.000119	7.95E-05

[1] AF percentiles calculated by the Kaplan-Meier Method.

Table 5.11 shows the AF values as a function of groundwater depth. The 95th percentile AFs from 5 - 15 feet and 15 - 25 feet decrease by two orders of magnitude, however, the 95th percentile of 25 - 40 feet and greater than 40 feet vary slightly and is in the same numerical range. Figure 5.8 shows the AFs at different depth ranges.

Figure 5.8 - Scatter plot for four depth ranges with trend line



5.12 AF Relationship with Lateral Distances for Groundwater

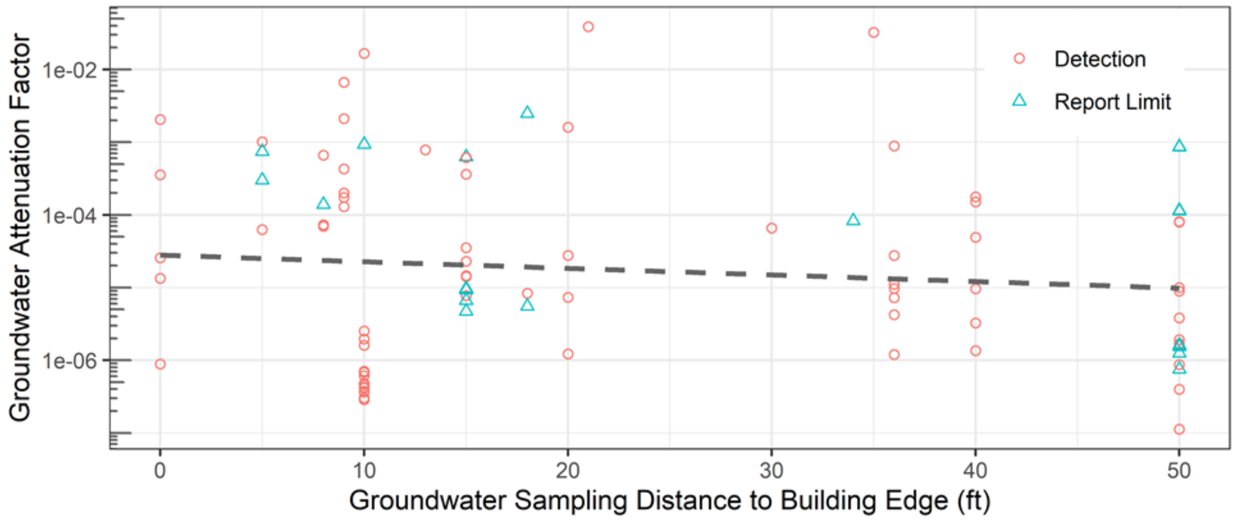
The AF was also calculated based on the lateral distances of groundwater samples from the edge of the buildings to evaluate whether a relationship can be discerned. Table 5.12 provides a summary of descriptive Statistics (50th, 75th, 90th, and 95th percentiles) at distances of less than 20 feet or greater than 20 feet from the building. The results neither show any correlation between AFs and the distances, nor are significantly different.

Table 5.12 - Descriptive Statistics (50th, 75th, 90th, and 95th percentiles) at two distance ranges

Distance Range	Number of Groundwater Data Pairs	No of Sites	%NDs	Groundwater AF percentiles[1]			
				95th	90th	70th	50th
<=20 ft	73	10	18	0.002048	0.00101	0.00013	2.50E-06
>20 ft	46	6	30	0.008479	0.000177	2.78E-05	3.80E-06

[1] AF percentiles calculated by the Kaplan-Meier Method.

Figure 5.9- Scatter plot for two distance ranges with trend line



6.0 Summary and Conclusions

DTSC's VI database presents the most comprehensive compilation of VI data to-date for CVOCs in California. DTSC, being the lead oversight agency on almost all the sites included in the database, with the exception of two sites, has a high level of confidence in the data quality. Additionally, DTSC staff assigned to a given site were consulted to ensure that measurements included and pairs formed are adequate and are representative of subsurface and indoor air contamination. The observations summarized here about empirical AFs are considered representative of VI of CVOCs from subsurface sources into buildings for most conditions commonly found in California. The SWRCB is also planning to develop California-wide AFs in the future and has modified their Geotracker database to gather data to meet its objective. It is hoped that DTSC data will eventually become part of the Geotracaker database and state-wide efforts to develop California AFs in the future. Therefore, the statistical distributions of AFs may change when the SWRCB's Geotracker database becomes populated with data from additional sites.

DTSC's VI database was compiled to help understand vapor attenuation that may be observed when vapors migrate from subsurface sources into indoor air spaces. After removing data that do not meet certain quality criteria and data likely to be influenced by indoor and outdoor background sources, the distributions of remaining AFs were analyzed graphically and statistically. The analyses indicate that it is important to consider the influence of background sources on empirical AFs so that the impacts due to VI can be distinguished.

Table 6.1 summarizes the subslab, soil gas, and groundwater AFs that remain after applying the baseline and source strength screens considered most effective at reducing the influence of background contributions to indoor air concentrations. These data demonstrate that the AF distributions obtained for subslab, soil gas, and groundwater are consistent with the conceptual model for VI, which predicts that greater attenuation is expected with greater depths to the vapor sources (Johnson and Ettinger, 1991). It should be noted that the data in Table 6.1 are not for a specific building type, but rather is an aggregate analysis of all building types in the database. Attenuation, relative to building type (residential versus non-residential buildings), is discussed below.

Table 6.1 - Descriptive Statistics for SS, SG, and GW AFs

Statistic	Subslab (SS>50X background)	Soil Gas (SG>50X background)	Groundwater (GW>100X background)
50th percentile	0.00007	0.00004	0.00001
75th percentile	0.0004	0.0002	0.0001
90th percentile	0.002	0.0005	0.0004
95th percentile	0.005	0.0009	0.001
Number of Pairs	600	2926	213
Number of Sites	32	39	16

[1] AF percentiles calculated by the Kaplan-Meier Method.

The range of AFs observed for subslab, soil gas, and groundwater span several orders of magnitude even after screening to minimize the influence of background sources on indoor air concentrations. This variability is due to the inherent variability in media concentrations and VI processes. DTSC's database includes information on specific building indoor spaces, operation of ventilation systems, and subsurface lithology but these data were not analyzed for their impact on potential variability and analysis is left to future vapor intrusion practitioners. Additionally, variability may also be introduced by the collection of non-representative subsurface samples when inappropriate sampling protocols are used. Thus, the observed range of AFs are expected given the variability in media concentrations, subsurface conditions, and building characteristics represented by the data compiled in the database.

6.1 Subslab AFs

The source-strength screening criterion of 50-times background was used to extract the subset of subslab soil gas AFs for CVOCs for California buildings because it represented the best screening criterion for minimizing the influence of background sources on the data. The following descriptive statistics were obtained for subslab attenuation as shown to one significant digit for residential and non-residential buildings (commercial and industrial).

Table 6.2 - Descriptive Statistics (50th and 95th percentiles) for Residential and Non-residential sites

Building Use	Number of pairs	Number of Sites	95th percentile	50th percentile
All Buildings	600	32	0.005	0.00007
Residential	42	3	0.02	0.002
Non-Residential	558	30	0.003	0.00006

[1] AF percentiles calculated by the Kaplan-Meier Method.

Observations about the analysis of subslab data from the database are:

- Most of the subslab sampling in California occurs at non-residential buildings. This is probably due to homeowner resistance to the invasive nature of subslab sampling and/or regulatory agencies' preference to by-pass such sampling and to directly sample indoor air to evaluate impacts to human health.

- After filtering for source strength, very few residential subslab AFs are available for statistical analysis, making any interpretations about the data challenging due to the lack of statistical robustness.

- Subslab AFs for non-residential buildings should be smaller than for residential buildings as indicated by the vapor intrusion conceptual model. Non-residential buildings are typically larger with higher indoor air exchange rates, thus non-residential buildings will dilute incoming vapors more than residential buildings. The statistics associated with subslab data agree with the VI conceptual model. However, while the difference between residential and non-residential AFs may be an order of magnitude, additional empirical data should be collected to verify the difference in attenuation between these two building types.

- The three sites that yielded 42 paired subslab measurements for residential buildings after source strength filtering are all in Southern California, making state-wide inference challenging.

6.2 Soil Gas AFs

The source-strength screening criterion of 50-times background was used to extract the subset of soil gas AFs for CVOCs for California buildings because it represented the best screening criterion for minimizing the influence of background sources on the data. The following descriptive statistics were obtained for soil gas attenuation for residential and non-residential buildings (commercial, industrial and schools).

Table 6.3 - Descriptive Statistics (50th and 95th percentiles) for Residential and Non-Residential Sites

Building Use	Number of pairs	Number of sites	95th percentile	50th percentile
All Buildings	2,926	39	0.0009	0.00004
Residential	1,485	6	0.0006	0.00005
Non-Residential	1,441	32	0.002	0.00003

[1] AF percentiles calculated by the Kaplan-Meier Method.

Observations about the analysis of soil gas data from the database are:

- Soil gas AFs for non-residential buildings should be smaller than for residential buildings as indicated by the VI conceptual model. Non-residential buildings are typically larger with higher indoor air exchange rates, thus non-residential buildings will dilute incoming vapors more than residential buildings. Hence, the statistics associated with soil gas data do not necessarily agree with the VI conceptual model. The difference between residential and non-residential AFs is a factor of 3, and additional empirical data should be collected to verify the difference in attenuation between these two building types.

- Seventy-six percent of residential AFs were collected from one site in Southern California, making state-wide inference challenging.

- Data in the database indicate that soil gas AFs change with depth. Sampling depths were distributed into three categories and comparison of the descriptive statistics demonstrate that soil gas AFs decrease with depth, as expected by the VI conceptual model. Vapor migrating through greater vadose zone distances should attenuate more than vapor migrating through shorter distances. As shown in the Table 6.4, deeper soil gas AFs change by a factor of 2.5 from approximately <10 to >20 feet as indicated by the 95th percentile.

Table 6.4 - Descriptive Statistics (50th and 95th percentiles) at Various Depth Intervals

Depth Range	Number of pairs	Number of sites	95th percentile	50th percentile
< 10 feet	1,334	32	0.001	0.0001
10 – 20 feet	1,036	28	0.0006	0.00004
> 20 feet	538	11	0.0004	0.000003

[1] AF percentiles calculated by the Kaplan-Meier Method.

- Data in the database indicate that soil gas AFs change with lateral (horizontal) sampling distance from a building. Lateral distances were distributed into four categories and comparison of the descriptive statistics demonstrate that soil gas AFs decrease with lateral distance from a building. As shown in the below table, lateral soil gas AFs change by a factor of 2.5 from approximately 10 to 50 feet as indicated by the 95th percentile. This change in AFs is probably attributable to proximity of the sample to the source of contamination. As sampling distances increase from a source area, vapor concentrations should likewise decrease and, hence, the AFs should also decrease.

Table 6.5 - Descriptive Statistics (50th and 95th percentiles) at four distance ranges

Lateral Range	Number of pairs	Number of sites	95th percentile	50th percentile
< 10 feet	498	19	0.001	0.00003
10 – 25 feet	526	15	0.001	0.00007
25 - 50 feet	834	16	0.0008	0.00004
> 50 feet	485	2	0.0004	0.00006

[1] AF percentiles calculated by the Kaplan-Meier Method.

6.3 Groundwater AFs

The source-strength screening criterion of 100-times background was used to extract the subset of groundwater soil gas AFs for chlorinated solvents for California buildings because it represented the best screening criterion for minimizing the influence of background sources on the data. The following descriptive statistics were obtained for groundwater attenuation.

Table 6.6 - Descriptive Statistics (50th and 95th percentiles) for groundwater AFs

Building Use	Number of pairs	Number of sites	95th percentile	50th percentile
All Buildings	213	16	0.001	0.00001

[1] AF percentiles calculated by the Kaplan-Meier Method.

Observations about the analysis of groundwater data from the database are:

- Due to the low number of paired groundwater measurements after source strength filtering, residential and non-residential AFs were not quantified.
- Groundwater AFs tend to be higher for deeper groundwater tables than for shallow groundwater tables, which is inconsistent with the VI conceptual model. This relationship is shown in the table below. It should be noted that the number of paired groundwater measurements is low.

Table 6.7 - Descriptive Statistics (50th and 95th percentiles) at three depth ranges

Depth Range	Number of pairs	Number of sites	95th percentile	50th percentile
15 – 25 feet	57	6	0.0004	0.000009
25 - 40 feet	59	6	0.002	0.000003
> 40 feet	50	2	0.001	0.00008

[1] AF percentiles calculated by the Kaplan-Meier Method.

6.4 Comparison of Results to Previous Studies

In the below table, the 95th percentile of AFs for subslab and soil gas are summarized for the existing empirical studies along with the results from the DTSC database. The data shown are for all building types within the studies.

Table 6.8-Results of subslab and soil gas AFs

Study	Subslab Attenuation Factor	Soil Gas Attenuation Factor
USEPA (2012)	0.03	0.3
Department of Defense (2015)	0.001	n/a
Ettinger and others (2018)	0.003	0.002
Derycke and others (2018)	0.04	n/a
Nawikas (2020)	0.004	n/a
DTSC (2020)	**0.005**	**0.0009**

USEPA (2012) and DoD (2015) are nationwide studies. Derycke and others (2018) is a nationwide study of schools in France, but Ettinger and others (2018) and Nawikas (2020) are California-specific studies. This comparison of empirical studies indicates that the results from the DTSC study may not be consistent with the results from France and EPA's nationwide study but are consistent with the results from the available California-specific studies and the study by the DoD. Accordingly, converging lines of evidence suggest that vapor attenuation in California is different from what is observed nationwide. The differences in attenuation may be due to climatic conditions and building structures common to California.

REFERENCES

Brenner, D. 2010. Results of a Long-Term Study of Vapor Intrusion at Four Large Buildings at the NASA Ames Research Center. Air and Waste Management Association, v. 60, p. 747 – 758.

Brewer, R., J. Nagashima, M. Rigby, M. Schmidt, and H. O'Neill. 2014. Estimations of Generic Subslab Attenuation Factors for Vapor Intrusion Investigations. Groundwater Monitoring and Remediaiton, v. 34, n. 4, p. 79 – 92.

California Environmental Protection Agency. July 2015. Advisory – Active Soil Gas Investigations. Joint Publication by Department of Toxic Substances Control, San Francisco Bay Regional Water Quality Control Board, and Los Angeles Regional Water Quality Control Board.

California Environmental Protection Agency. February 2020. Supplemental Guidance: Screening and Evaluating Vapor Intrusion; Draft for Public Comments. Jointly written by California Department of Toxic Substance Control and California Water Resources Control Boards.

Department of Defense. June 2015. A Quantitative Decision Framework for Assessing Navy Vapor Intrusion Site. Naval Facilities Engineering Command Technical Report, TR-NAVFAC –EXWC-EV-1603.

Department of Toxic Substances Control. October 2011. Final Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air (Vapor Intrusion Guidance). California Environmental Protection Agency, Department of Toxic Substances Control.

Derycke, V., A. Coftier, C. Zornig, H. Leprond, M. Scamps, and D. Gilbert. 2018. Environmental Assessments on Schools Located On or Near Former Industrial Facilities: Feedback on Attenuation Factors for the Prediction of Indoor Air Quality. Science of the Total Environment, v. 626, p. 754 – 761.

Eklund, B., S. Burkes, P. Morris, and L. Mosconi. 2008. Spatial and Temporal Variability in VOC Levels within a Commercial Retail Building. Indoor Air, v. 18, p. 365–374.

Eklund, B., L. Beckley, and R. Rago. 2018. Overview of State Approached to Vapor Intrusion: 2018. Remediation, v. 28, p. 23 – 35.

Ettinger, R. A., S. Luis, N. Weinberg, T. McAlary, G. Plantz, H. Dawson, and J. Sickenger. 2018. Empirical Analysis of Vapor Intrusion Attenuation Factors for Subslab and Soil Vapor – An Updated Assessment for California Sites. In the Proceedings of the Air and Waste Management Association's Vapor Intrusion, Remediation, and Site Closure Conference, December 5 – 6, Phoenix, Arizona, Paper No. VI22.

Holton, C., H. Luo, P. Dahlen, K. Gorder, E. Dettenmaier and P.C. Johnson. 2013. Temporal Variability of Indoor Air Concentrations under Natural Conditions in a House Overlying a Dilute Chlorinated Solvent Groundwater Plume. Environmental Science & Technology, n. 47, p. 13347-13554.

Johnson, P.C. and R.A. Ettinger. 1991. Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors into Buildings. Environmental Science & Technology, n. 25, p. 1445–1452.

Johnson, P.C. 2005. Identification of Application-Specific Critical Inputs for the 1991 Johnson and Ettinger Vapor Intrusion Algorithm. Ground Water Monitoring & Remediation, v. 25, n. 1, p. 63-78.

Luo, H., P. Dahlen, P.C. Johnson, T. Peargin, and T. Creamer. 2009. Spatial Variability of Soil-Gas Concentrations Near and Beneath a Building Overlying Shallow Petroleum Hydrocarbon-Impacted Soils. Ground Water Monitoring & Remediation, v. 29, n. 1, p. 81-91.

McHugh, T.E., T.N. Nickels, and S. Brock. 2007. Evaluation of Spatial and Temporal Variability in VOC Concentrations at Vapor Intrusion Investigation Sites. In Proceedings of Air & Waste Management Association. Vapor Intrusion: Learning from the Challenges, September 26–28, Providence, Rhode Island, p. 129–142.

Nawikas, S. 2020. Subslab to Indoor Air Attenuation Factors Determined from Radon Data. Presentation Slides from Certified Unified Program Agency California Forum, February 5, Burlingame, California.

Pennell, K. G, M. K. Scammell, M. D. McClean, E. M. Suuberg, A. Moradi, M. Roghani, J. Ames, L. Friguglietti, P. A. Indeglia, R. Shen, Y. Yao, and W. J. Heiger-Bernays. 2016. Field Data and Numerical Modeling: A Multiple Lines of Evidence Approach for Assessing Vapor Intrusion Exposure Risks. Science of the Total Environment, v. 556, p. 291 – 301.

R Core Team. 2019. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria; Website: https://www.R-project.org.

State Water Resources Control Board. August 17, 2012. Low-Threat Underground Storage Tank Case Closure Policy. California Environmental Protection Agency.

United States Department of Housing and Urban Development. 2017. American Housing Survey Table Creator, General California Housing Data – All Occupied Structures. Survey Conducted by the United States Census Bureau.

United States Environmental Protection Agency. March 2009. Statistical Method of Groundwater Monitoring Data at RCRA Facilities. Office of Office of Resource Conservation and Recovery, Publication EPA 530-R-09-007.

United States Environmental Protection Agency. March 16, 2012a. EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings. Office of Solid Waste and Emergency Response, Publication EPA 530-R-10-002.

United States Environmental Protection Agency. February 2012b. Conceptual Model Scenarios for the Vapor Intrusion Pathway. Office of Solid Waste and Emergency Response.

United States Environmental Protection Agency. June 2015. OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air. Office of Solid Waste and Emergency Response; Publication 9200.2-154.

Yao, Y.J., R. Shen, K.G. Pennell and E.M. Suuberg. 2013. A Review of Vapor Intrusion Models. Environmental Science and Technology, n. 47, p. 2457 - 2470.

Yao, Y., I. Verginelli, E. M. Suuberg, and B. Eklund. 2018. Examining the Use of USEPA's Generic Attenuation Factor in Determining Groundwater Screening Levels for Vapor Intrusion. Groundwater Monitoring and Remediation, v. 38, n. 2, p. 79 – 89.

Figure 1.1
Location of Sites in DTSC's Empirical Vapor Intrusion Database

Table 2.1 - Summary of Information in DTSC's Empirical Vapor Intrusion Database

	City	Soil Type	No. of Bldgs	Bldg Use		Media Sampled					Chemicals						
							Soil Gas										
				Residential	Commercial / Industrial	Groundwater	Inside	Outside	Total	Subslab	TCE	PCE	1,2-DCE	cis-1,2-DCE	trans-1,2-DCE	Vinyl Chloride	1,1,1-TCA
2371 San Pablo Avenue	Berkeley	Clay	1		1		2	2	4			●					
4906 Alcoa	Vernon	Mixed	1		1		28	4	32	2	●	●					
6801 Suva Street and 6814 Foster Bridge Blvd. Properties	Bell Gardens	Mixed	1		1		22		22		●	●					
Ace Clearwater	Paramount	Mixed	4		4	26				18	●	●					●
Aerojet General Corporation	Rancho Cordova	Mixed	3		3					90	●	●	●	●	●	●	
Alumin Art Plating	Ontario	Unknown	1	1						12	●	●	●	●	●	●	
Amco Chemical	Oakland	Mixed	4	2	2			22	22		●	●	●				
Carmel Cleaners	Carmel	Mixed	3		3					18	●	●	●	●	●	●	
Carroll Shelby Enterprises	Los Angeles	Silt	2		2	28					●	●					
Chicago Musical Instrument	Fullerton	Coarse	1		1			8	8		●	●	●	●			
Cla-Val	Costa Mesa	Mixed	1		1					34	●	●					
Conoco Philips Los Angeles Terminal	Los Angeles	Clay	5		5		26		26	46	●	●	●		●	●	
Cornell-Dublier Electronics	Marina Del Rey	Mixed	4		4		18	27	45	27	●	●		●			
Coronet Cleaners	Fremont	Mixed	1		1	2		8	8	8	●	●					

Table 2.1 – Summary of Information in DTSC's Empirical Vapor Intrusion Database (continued)

	City	Soil Type	No. of Bldgs	Bldg Use		Media Sampled					Chemicals						
							Soil Gas										
				Residential	Commercial / Industrial	Groundwater	Inside	Outside	Total	Subslab	TCE	PCE	1,2-DCE	cis-1,2-DCE	trans-1,2-DCE	Vinyl Chloride	1,1,1-TCA
Crieghton's Cleaners	Long Beach	Mixed	2		2	16	6		6	10	●	●					
E Street Plaza Shopping Center	Chula Vista	Mixed	2	1	1			54	54	5	●	●		●		●	
Embee Plating	Santa Ana	Mixed	2		2					35	●	●	●	●		●	
Ford Aeronautics Property	Newport Beach	Silt	43	43				1342	1342		●						
Former Flamingo Cleaners (LA Source)	Santa Clarita	Mixed	1		1	4	6		6	3	●	●					
Former Kast Property	Carson	Mixed	48	48						183		●					
Former Norge / Atherton Village Cleaners	Menlo Park	Mixed	1		1					2		●					
Former Quality Dry Cleaning	Petaluma	Clay	1		1	11	10		10		●	●		●			
Former Service Cleaners	Modesto	Mixed	1		1	6		30	30		●	●		●		●	
General Atomics	San Diego	Mixed	1		1		18		18	6	●	●					
Green's Cleaners	South Gate	Silt	3	1	2		115	713	828	64	●	●	●	●	●	●	
Hughes Torrance	Torrance	Mixed	2		2		45		45	8	●	●					
Magnolia Elementary School	El Cajon	Mixed	16		16			117	117		●	●	●	●		●	
MJ Plating	Northridge	Mixed	1		1		36		36		●	●	●	●	●	●	
Modesto Groundwater Investigation	Modesto	Mixed	2		2	3		3	3	3	●	●		●			

Table 2.1 – Summary of Information in DTSC's Empirical Vapor Intrusion Database (continued)

	City	Soil Type	No. of Bldgs	Bldg Use		Media Sampled					Chemicals						
							Soil Gas										
				Residential	Commercial / Industrial	Groundwater	Inside	Outside	Total	Subslab	TCE	PCE	1,2-DCE	cis-1,2-DCE	trans-1,2-DCE	Vinyl Chloride	1,1,1-TCA
Mountain Square Cleaners	Upland	Mixed	1		1		39	11	50	15	●	●	●	●	●	●	
National Steel & Shipbuilding Company	San Diego	Unknown	2		2	10				20		●					
New Los Angeles Charter School	Los Angeles	Mixed	1		1		18	12	30	61	●	●	●	●	●	●	
North Island Naval Air Station	San Diego	Silt	9		9					318	●	●	●	●	●	●	
Old Orchard Shopping Center	Santa Clarita	Mixed	1		1		22	17	39		●	●					
One Hour Martinizing Mooney	Visalia	Silt	1		1			6	6			●					
Ontario Plaza	Ontario	Coarse	1		1		16	60	76			●					
Pacific Scientific	Santa Barbara	Mixed	3		3			47	47	70	●	●	●	●	●	●	
Palm Grove Apartments	Lompoc	Clay	2	2				5	5			●					
Penetrate Metal Processing	Los Angeles	Mixed	4	3	1		198	42	240		●	●	●	●	●	●	
PK I County Fair Sc Lp	Chino	Mixed	1		1		65	5	70	24	●	●	●	●	●		
Plaza By The Sea	San Clemente	Coarse	1		1					12	●	●					

Table 2.1 – Summary of Information in DTSC's Empirical Vapor Intrusion Database (continued)

	City	Soil Type	No. of Bldgs	Bldg Use		Media Sampled					Chemicals						
				Residential	Commercial / Industrial	Groundwater	Soil Gas			Subslab	TCE	PCE	1,2-DCE	cis-1,2-DCE	trans-1,2-DCE	Vinyl Chloride	1,1,1-TCA
							Inside	Outside	Total								
Polo Cleaners	Mission Viejo	Coarse	1		1		30		30		●	●				●	
Quality Cleaners (Aka Tracy Corners)	Tracy	Clay	1		1	30					●	●		●	●	●	
Safety-Kleen San Jose	San Jose	Mixed	1		1	6				36	●	●	●	●	●	●	
Shachihata, Inc.	Harbor City	Coarse	1		1		12		12	14	●	●					
Sunshine Cleaners	El Cerrito	Mixed	1		1	8				12	●	●		●			
TC Rich LLC/Former Pacifica Chemical Inc.	Los Angeles	Mixed	1		1	59	32	27	59		●	●		●			
Torrance Memorial Specialty Center	Torrance	Unknown	1		1					21	●	●	●				
Turco Products Inc. #1	Carson	Mixed	3		3		28	10	38	12	●	●		●			
Whitcomb Plating	City Of Industry	Silt	2		2	9				7	●	●					
World Cleaners / Richard Cleaners	San Pedro	Mixed	1		1	8		42	42			●					
Wyle Laboratories	Norco	Coarse	12	12		41		103	103		●						
TOTAL			**213**	**113**	**100**	**267**	**792**	**2717**	**3509**	**1196**							

Appendix 1
Summary of Statistical Computing

R is a programing language and environment for statistical computing and graphics, developed at Bell Laboratories (formerly AT&T, now Lucent Technologies) in 1976 by John Chambers and colleagues. R provides a wide variety of statistical and graphical techniques. One of R's strengths is the ease with which well-designed publication-quality plots can be produced, including mathematical symbols and formulae where needed. R is available as free software under the terms of the Free Software Foundation's GNU General Public License in source code form. It compiles and runs on a wide variety of UNIX platforms, Linux, Windows, and MacOS.

R is an integrated suite of software facilities for data manipulation, calculation and graphical display. It includes:

- An effective data handling and storage facility
- A suite of operators for calculations on arrays and matrices
- A large, coherent, integrated collection of intermediate tools for data analysis
- Graphical facilities for data analysis and display either on-screen or on hardcopy
- A well-developed, simple and effective programming language which includes conditionals, loops, user-defined recursive functions and input and output facilities.

R is designed as a true computer language and allows its users to add additional functionality by defining new functions. Much of the system is itself is written in the R dialect of S, which makes it easy for users to follow the algorithmic choices made. For computationally intensive tasks, C, C++ and Fortran code can be linked and called at run time. Advanced users can write C code to manipulate R objects directly. R can be easily augmented with "packages." There are about eight packages supplied with the R distribution and many more are available on the internet covering a very wide range of modern statistics. R has its own comprehensive documentation, both on-line in a number of formats and in hardcopy.

Appendix 2

Statistical Analysis Report

Data Processing and Analysis for California Vapor Intrusion Database of the Department of Toxic Substance Control

Jing Tao, Ph.D.

Research Scientist III

Office of Environmental Health Hazard Assessment

July 16, 2020

Contents

List of Acronyms and Abbreviations

1,1,1-TCA	1,1,1-trichloroethane
1,1-DCE	1,1-dichloroethene
AF	Attenuation Factor
Aggregate dataset	Vapor intrusion dataset combining data of seven chemicals
Bkgd	Background concentration
CARB	California Air Resources Board
C_{IA} or IA	Indoor air concentration
C_S	Subsurface vapor concentration, including SS, SG, and GW
cis-1,2-DCE	cis-1,2-dichloroethene
CVOC	Chlorinated volatile organic compound
DTSC	Department of Toxic Substances Control
GW	Groundwater vapor concentration
KM	Kaplan-Meier method
MDL	Method Detection Limit
MLE	Maximum Likelihood Estimation
ND	Non-detect
OEHHA	Office of Environmental Health Hazard Assessment
PCE	tetrachloroethylene
RL	Reporting Limit
ROS	Regression on Order Statistics
SG	Soil gas concentration
SS	Subslab vapor concentration
SUB	Substitution method
TCE	trichloroethylene
trans-1,2-DCE	trans-1,2-dichloroethene
USEPA	United States Environmental Protection Agency
VC	vinyl chloride
VI	Vapor Intrusion

Introduction

The Department of Toxic Substance Control (DTSC) gathered data from sites contaminated with chlorinated volatile organic compounds (CVOCs) and developed a vapor intrusion (VI) database to evaluate empirical VI attenuation factors (AF) of buildings in California (DTSC, 2020). The database was provided to the Office of Environmental Health Hazard Assessment (OEHHA) for analysis. DTSC requested OEHHA to summarize descriptive statistics and provide data plots for outdoor air concentrations and subslab, soil gas, and groundwater AFs. The data analysis needed to incorporate non-detectable concentrations reported in the database. Following the approach documented in the United States Environmental Protection Agency (USEPA) 2012 report (USEPA, 2012), multiple steps of data screening were applied to select subsets of AF data, for which subsurface sources of vapors (instead of background sources) were likely to be the primary contributor of CVOC indoor air concentrations (DTSC, 2020). The data distributions were summarized as AF percentiles after each step of data screening. For selected data subsets, the AF percentiles were estimated for residential and non-residential buildings, and by sampling depths and lateral locations. In addition, percentiles of AFs and outdoor concentrations were estimated for individual chemicals before data screening. DTSC (2020) used the results of the analysis to determine the media-specific AFs and provided an understanding of the technical aspects of VI.

This report documents the processing and analysis procedure to fulfill the request of DTSC and generate figures and statistics for the DTSC report (DTSC, 2020). All the data processing and analysis used the statistical software R version 3.6.1 (R Core Team, 2019). R is one of the most commonly used data science tools and creates reproducible and durable analytics. It is widely used for data analytics, statistical inference, graphical plots, time series analysis, and so on. It provides powerful statistical computing for all types of research, enabling data-driven decision-making in fields such as environmental protection and public health assessment. The DTSC VI database used Microsoft Excel as the platform and was not structured as a database with relational tables, which necessitated some pre-processing before extracting and analyzing the data. This report demonstrates an example of coding practice to accomplish these data analysis objectives. This report (the OEHHA report) focuses on processing, visualization, and statistical summaries of the data. Data collection and database development were documented in the DTSC report, as well as professional judgement for the VI evaluation (DTSC, 2020).

Pre-processing Data

Description of the database

The DTSC VI database spreadsheet contains 4821 rows and 82 columns of data. Columns include site and building information, chemical name, indoor and outdoor air concentrations, vapor concentrations from three subsurface media (subslab, soil gas, groundwater), and respective sampling information (DTSC, 2020). All the identification fields (i.e. site name, building name, sample identification number) in the database used the names or the numbers as-is in the original site assessment reports. The database does not have systematic identifiers for sites, buildings, samples, or concentration measurements. The database was structured to estimate all possible AFs for the three types of subsurface media. For this purpose, an indoor concentration of a chemical was paired with subsurface data if the subsurface data was collected within three months. A single concentration measurement can appear in multiple rows of data, and one row of data can have 0 – 3 estimated AFs. Outdoor concentrations were not used for the AF estimation but provided additional information.

A substantial proportion of the concentration data were reported as ND (non-detect). The attenuation factors were calculated with the indoor air concentrations (C_{IA}) and the subsurface vapor concentrations (C_S) as shown in eq. 1:

$$\mathrm{AF} = \frac{C_{IA}}{C_S} \qquad [1]$$

When directly calculating AFs with measurements recorded as NDs in the Microsoft Excel, error messages were generated and the AF variables cannot be properly summarized.

The DTSC VI database provided the method detection limits (MDL) and/or the reporting limits (RL) for most of the reported NDs. The MDL is the lowest concentration of a chemical that the analytical method could reliably detect. A chemical concentration reported as ND may contain a concentration at any value between 0 and its MDL. The RL is the lowest value that a laboratory reports without qualifications. The RL is usually higher than the MDL. Both limits are characteristics of the method, the chemical, and the lab. The information hidden behind the ND records in the DTSC VI database varied due to the differing MDL and RL levels provided in the original site assessment reports. In this report, “reporting limit” or RL is used as a generalized term for both types of thresholds for concentrations. It is also a term that refers to a calculated threshold for the AF of a non-detected C_{IA}, which is described in the next section, pre-processing procedure.

Overall, pre-processing data is necessary for several reasons:

[1] To check and correct names, formatting, and values of columns used for analysis;

[2] To identify unique site, building, and sample records for concentration summaries and group comparisons;

[3] To report, store, and use AFs for concentrations recorded as NDs;

[4] To extract AFs and related columns to create data subsets for analysis on subslab, soil gas, and groundwater AFs.

Pre-processing procedure

Figure 1 exhibits the procedure to pre-process the DTSC VI data for the AF analysis in this report. The data was collected from 52 sites statewide. An individual site can be identified by the site name. All the missing values including empty cells, Excel error messages, and "unknown" values were unified as "NA" (not available) before further processing.

Because of the positions of subsurface vapor concentrations (C_S) and indoor air concentrations (C_{IA}) in the AF equation (eq. 1), their NDs need to be treated differently in the pre-processing. When a C_S (the denominator) is an ND, the resulting ratio (AF) has an infinite range and cannot be used in statistical analysis. The C_S has to be a quantifiable value (detected measurement) in order to determine a value or a limited range for the AF. Therefore, all NDs in C_S were considered to be unfixable missing data and converted to "NA".

On the other hand, NDs of C_{IA} were replaced with their associated MDLs or their RLs if MDLs are not available. RL in this report refers to all the replaced values. A new column (nd_flag) with two logical values was created to flag replaced and quantifiable concentrations ("Yes" if C_{IA} is a RL; "No" if C_{IA} is a quantifiable concentration). AFs were recalculated with new concentration values.

After the processing, AFs calculated with concentration NDs were also NDs, and they were stored as the calculated thresholds (RL of AF, calculated from RL of C_{IA} and quantifiable C_S) of each respective AF in the database. These non-detectable AFs can be distinguished from quantifiable AFs (calculated from quantifiable C_{IA} and C_S) by nd_flag. Their true values are considered to be any number between 0 and the calculated RL. Meanwhile, a C_S as "NA" generated an AF of "NA", which represented a missing value and was not used in the analysis.

Finally, three sets of data were extracted from the processed database for available subslab, soil gas, or groundwater AFs. Further data screening and AF analysis were performed starting from these three aggregate datasets.

Besides AFs, outdoor air concentrations were extracted for a summary. Individual measurements of outdoor concentrations were identified using unique combinations of the sampling information. A new column was created to flag all the ND records in outdoor concentrations, and the NDs in the concentration column were replaced with associated RLs. Some outdoor concentrations were reported as 0. A consultation with the DTSC revealed that records reported as 0 were unreliable measurements and were therefore removed for the analysis. Outdoor data included two chemicals: Tetrachloroethylene (PCE) and Trichloroethylene (TCE). Data were evaluated and summarized for each chemical.

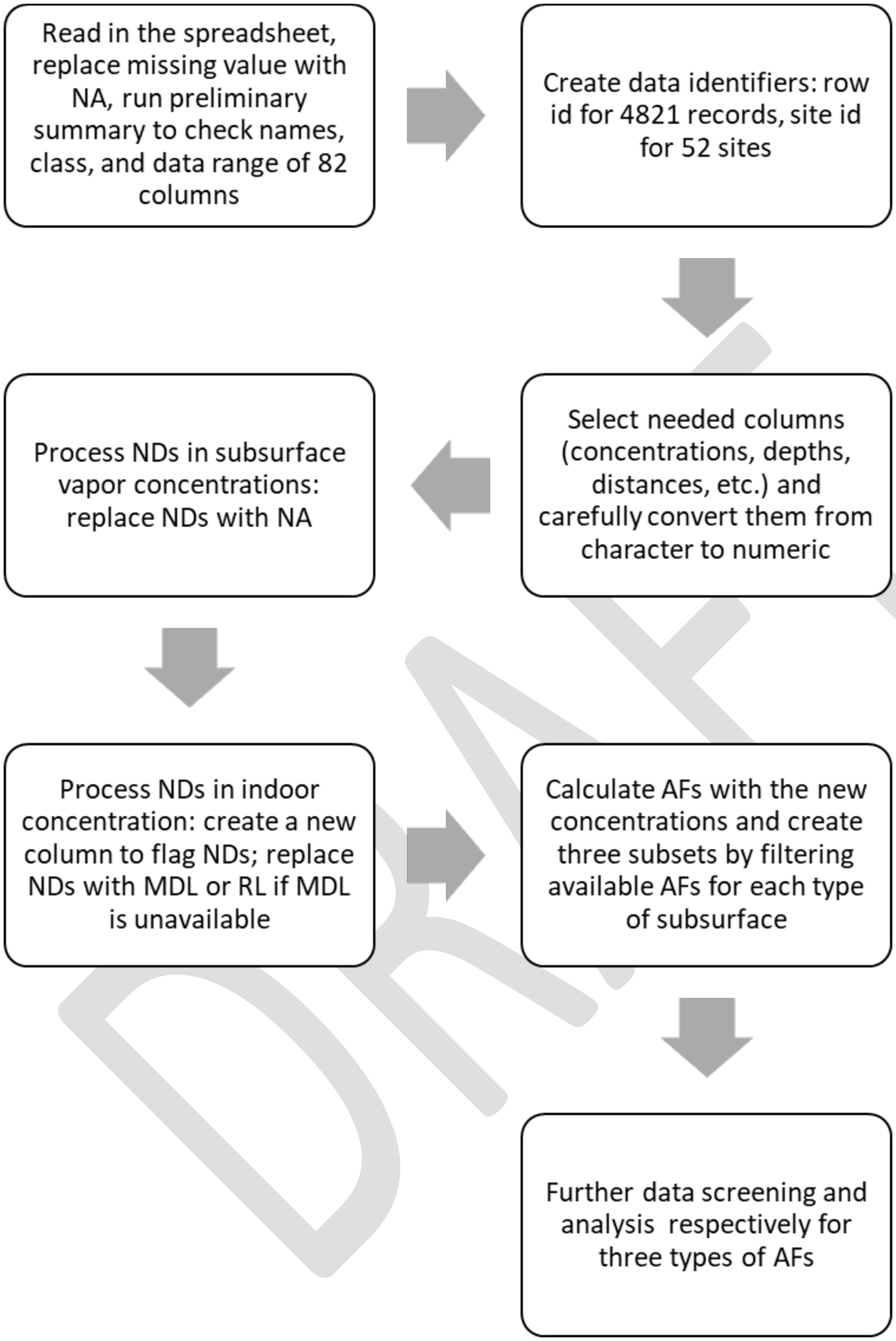


Figure 1. Pre-processing procedure for the vapor intrusion data analysis

Data Screening and Analysis Method

As requested by the DTSC, the summary for empirical AFs followed the approach documented in the USEPA 2012 report. USEPA used aggregated data from all chemicals to estimate the percentiles for empirical AFs (USEPA, 2012). The DTSC VI database collected data on eight chemicals including PCE, TCE, 1,1-dichloroethene (1,1-DCE), cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-dichloroethene (trans-1,2-DCE) , 1,1,1-trichloroethane (1,1,1-TCA), vinyl chloride (VC), and radon. The analysis documented in this report used data on the seven chlorinated solvents (radon was excluded).

Data screening procedure

Because of the potential contributions of background sources to indoor air concentrations, USEPA (2012) developed a series of screening criteria to generate subsets of data for AF analysis and aimed to reduce the impact of background sources on the summary statistics of empirical AFs. The analysis for the DTSC VI data employed a similar screening procedure (Figure 2).

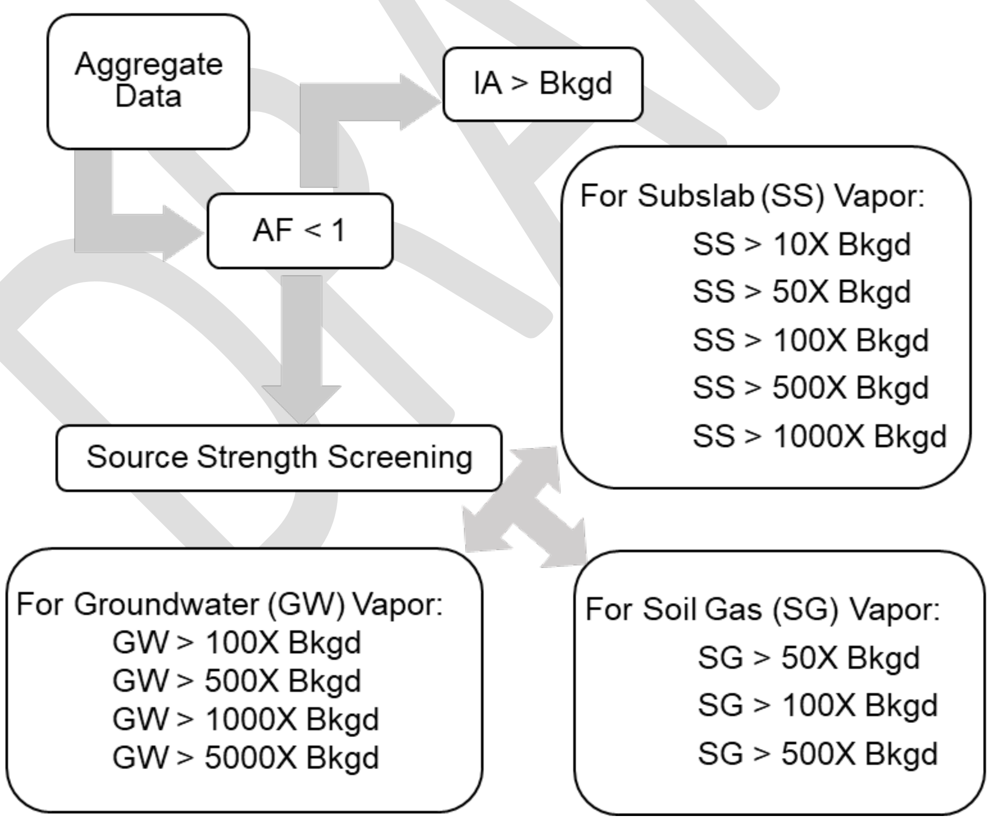


Figure 2. Flowcharts of data screening for three types of attenuation factors (AF) with a background concentration (Bkgd) of 1.36 µg/m^3. (IA = Indoor Air Concentration)

The first screening step was to select values with AF < 1; C_{IA} should be lower than C_S if VI was the sole source of C_{IA}.

After initial screening, several screening steps were conducted separately using a pre-determined background reference concentration to further select subsets of subslab, soil gas, and groundwater AFs. DTSC, in consultation with OEHHA, determined the background reference concentration as 1.36 µg/m^3 using the ambient air monitoring data collected by the California Air Resources Board (CARB). This reference concentration was the median of the 10-year maximum concentrations of PCE measured in the ambient air of California (DTSC, 2020). It was considered to represent a reasonable upper bound background concentration of all chemicals in the DTSC VI database. The screening steps using the background concentration included selecting AFs with C_{IA} > background (IA > Bkgd) and source strength screening, which selected the data with C_S larger than the products of the background concentration and a series of multipliers (Figure 2). These steps select data subsets with comparatively high C_{IA} or high C_S. Since the impact of other sources could be relatively lower in these subsets, the empirical AFs may better represent the VI and provide better estimates for decision-making.

Exploratory plots

After pre-processing, AFs had two types of values: [1] quantifiable numeric values designated the logical value “No” in the nd_flag column; and [2] NDs stored as values of RLs in the AF columns and the logical value “Yes” in nd_flag. An AF at a RL level was calculated from the RL of a C_{IA} that was originally reported as ND.

Similar to the USEPA (2012), this report uses distribution plots such as boxplots and density plots to exhibit the AF distributions on a log10 scale after each step of screening. These plots used all the reported values in AFs but cannot account for the nd_flag column. Therefore, NDs for AFs were shown at the levels of their calculated RLs. The distribution plots can only be used to explore, not to estimate, the data distribution. The lines in boxplots summarizing the median, 25th percentile, 75th percentile, and so on showed the upper limits of the statistics, so they may not precisely represent the percentiles estimated by the Kaplan Meier (KM) method used in the analysis. The R package “ggplot2” (Wickham, 2016) was used to create all the exploratory plots including scatter plots and distribution plots in both the DTSC report and the OEHHA report.

Descriptive statistics summary

Descriptive statistics need to be summarized for the AFs by different groupings, including by chemicals, building use types, depth ranges, and distance ranges.

To summarize descriptive statistics for data with NDs, traditional “substitution” methods replace NDs in a column of measurements with specific values (e.g. MDL, MDL/2, RL, RL/2) then perform the summary for the data column. The substitution methods have been criticized because they assumed a uniform distribution for NDs and could distort the data variation (Helsel, 2012). The USEPA report (2012) applied the Kaplan-Meier (KM) method in a function spreadsheet provided by Helsel (2005) to summarize percentiles of the AF data. Helsel (2012) is the latest version of the book and the reference of this analysis. The R package “NADA” developed by Lee (2017) to implement the procedure described by Helsel (2012) was used to perform the estimation in this analysis.

Helsel (2012) introduced several methods to summarize data involving NDs. These methods, including Maximum Likelihood Estimation (MLE), Regression on Order Statistics (ROS), and KM all need two columns as inputs to perform the estimation: the numeric measurement (AF or concentration in this analysis) and nd_flag. MLE is a parametric method and requires a correct assumption of data distribution. It is difficult to assume a distribution for AFs in the DTSC VI database for several reasons:

[1] An AF is a ratio of two concentrations which were manually paired together;

[2] The concentrations were collected from multiple studies over 10 years with various levels of RLs;

[3] Reliable references for AF distributions were not available.

ROS also assumes a distribution, but only to impute values reported as NDs and uses quantifiable values as their own. ROS is more robust than MLE, but it cannot generate summary statistics by groups.

Kaplan-Meier is a non-parametric method, which does not assume a distribution. The KM method calculates a probability for each quantifiable value based on the rank and number of detections at the value. The probabilities are not calculated for the data reported as NDs, but the counts of these data points affect the ranks of detections that are above their RLs. All the calculated probabilities form an empirical cumulative distribution and are used to estimate percentiles. If the highest RL is above all the detections, its NDs are not counted in the estimation. Helsel (2012) recommended use of the KM method to summarize data with less than 50% NDs. With more than 50% NDs, less than half of data points can be assigned with probabilities to build the empirical distribution, causing the estimates of percentiles to have high uncertainties. The KM method can handle multiple RLs and provide summary statistics by groups.

This analysis used the KM method to estimate percentiles for AFs and outdoor air concentrations. Other methods including summary on detections and substitution methods were also used to analyze outdoor concentrations and evaluate the background concentration of 1.36 μg/m^3 within the range of outdoor concentrations. The substitution methods with RL or RL/2 actually used MDLs or RLs if MDLs were not available. The AF percentiles estimated by KM are compared with the results of MLE, ROS, and substitution methods to evaluate the method in the summary and discussion section.

Comparison and Regression

Four types of building use were reported in the DTSC VI database: commercial, industrial, school, and residential. Because residential buildings represented different exposure scenarios than the other buildings, the AFs were classified into two categories: residential buildings and non-residential buildings (commercial, industrial, and school). The KM method was used to estimate the AF percentiles for each category.

The Peto-Prentice test was performed to compare AFs of two categories using the R package “NADA” (Helsel, 2012; Lee, 2017). The Peto-Prentice (or Peto-Peto) test is a version of generalized Wilcoxon test. It is a type of non-parametric score test to examine whether empirical cumulative distributions of two or more groups are significantly different. In this test, a score is calculated for each observation based on its probability and observation type (detection or ND) (Helsel, 2012). If the null hypothesis is true (that groups have the same distributions), observations from each group should be randomly scattered and the sum of scores for observations should be close to 0. The observation scores are summed by group and compared to their expected score sum. The statistic calculated from the squared score difference and an empirical variance has a chi-square distribution with k – 1 degrees of freedom (k is the count of groups). A p-value lower than 0.05 suggests that groups may have different empirical distributions.

To analyze the correlation between AFs and sampling depths or lateral locations, regression analysis was required to quantify the average change of a response variable (AF) caused by a unit change of an independent variable (depth or distance). The MLE method in the “NADA” package can perform regression analysis for the variables with NDs. The log normal distribution was assumed in the estimation and a residual plot was generated to examine the assumption.

DTSC was particularly interested in the AF distributions within several depth ranges (3 ranges for soil gas and 4 ranges for groundwater) and distance ranges (4 ranges for soil gas and 2 ranges for ground water). The KM method was applied to summarize AF percentiles by these groups. The Peto-Prentice test compared AF distributions of different groups. The results of both MLE and Peto-Prentice were reviewed to evaluate if AFs could significantly change with soil gas or groundwater sampling at different depths and distances. It should be noted that these methods have limitations to accurately quantify the effect, which are discussed within the results section.

Results

Summary of outdoor air concentrations

The outdoor air concentration columns were comprised of measurements of two chemicals, Tetrachloroethylene (PCE) and Trichloroethylene (TCE). After pre-processing, there are 212 data points (14% NDs) of PCE and 191 data points (64% NDs) of TCE. Concentration distributions show different patterns between the two chemicals (Figure 3). Neither of them followed a normal or a lognormal distribution. Quantifiable concentrations of PCE ranged from 0.024 – 64 µg/m^3 and TCE ranged from 0.021 – 6.1 µg/m^3. Both chemicals had a large range of RLs (PCE: 0.0099 – 6.9 µg/m^3; TCE: 0.0071 – 5.0 µg/m^3) with a limited number of detections greater than the highest RLs (Figure 3).

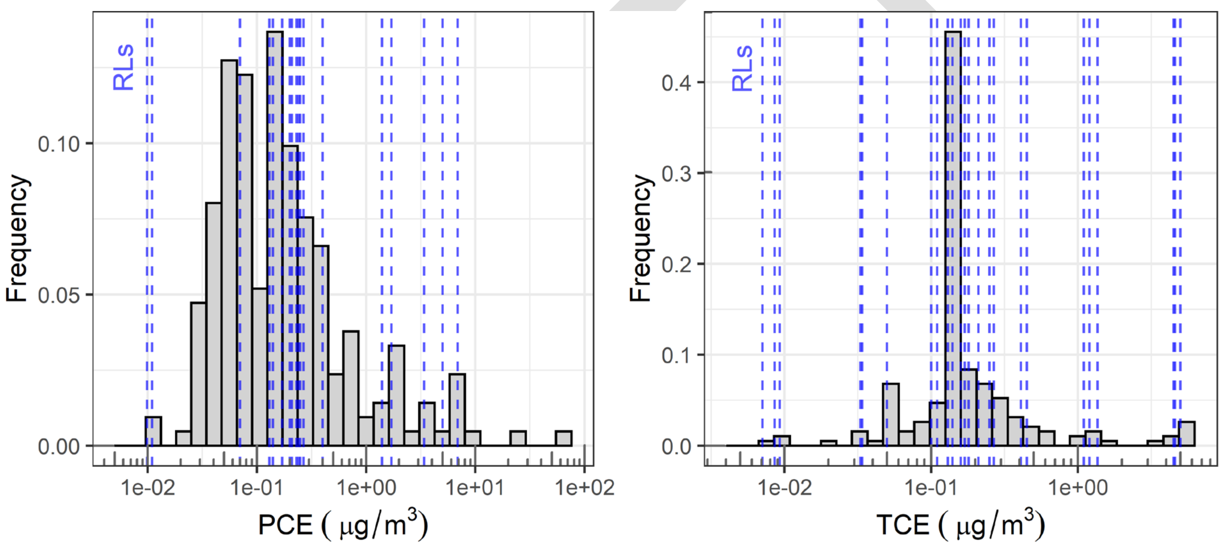


Figure 3. Histogram of outdoor air concentrations on log10 scales with discrete reporting limits (RLs). All the non-detected concentrations are shown at their report limit levels

Table 1 summarizes the percentiles of outdoor concentrations using the KM method and three other computing methods, including summary on detections only, and summary on two options of substituting data (substituting NDs with values of RL/2 or RL). The median (the 50th percentile) of outdoor concentrations estimated by KM and the substitution methods were similar for both PCE and TCE data. The percentiles above the median (the 75th – 95th) estimated by KM were lower than those of the two substitution approaches. For PCE, which had a relatively smaller proportion of NDs, summary on 183 detections produced results close to other methods with total 212 data points. All the estimates for TCE had high uncertainties because of high percentages of NDs. For TCE, KM estimates were lower than other approaches in all percentiles. The background concentration of 1.36 μg/m^3 used for the data screening in this report is higher than 90% of PCE and TCE outdoor air concentrations reported in the DTSC VI database, but lower than their maximum detections. Therefore, the concentration of 1.36 μg/m^3 is a reasonably high value of environmental background concentration.

Table 1. Percentile summary of outdoor air concentrations

A. PCE

Summary Method	n	ND%	5th %tile	25th %tile	50th %tile	75th %tile	90th %tile	95th %tile
Kaplan-Meier	212	13.7	0.03	0.06	0.10	0.29	0.64	1.80
Detections only	183	0	0.03	0.06	0.13	0.31	0.69	1.86
ND substituted with RL/2	212	13.7	0.03	0.06	0.12	0.31	0.86	2.17
ND substituted with RL	212	13.7	0.03	0.06	0.15	0.32	1.34	3.40

B. TCE

Summary Method	n	ND%	5th %tile	25th %tile	50th %tile	75th %tile	90th %tile	95th %tile
Kaplan-Meier	191	63.9	-	0.04	0.07	0.12	0.33	0.55
Detections only	69	0	0.05	0.09	0.21	0.35	0.72	4.42
ND substituted with RL/2	191	63.9	0.03	0.07	0.07	0.18	0.45	0.79
ND substituted with RL	191	63.9	0.05	0.13	0.13	0.22	0.45	1.36

AF summary by chemical

Figure 4 and Table 2 summarize attenuation factors by chemical before data screening. PCE and TCE comprise 83% of data points in subslab and soil gas AFs, and 92% in groundwater AFs. PCE and TCE were measured in subslab samples at 24 and 32 sites respectively, in soil gas samples at 29 and 33 sites, and in groundwater samples at 11 and 15 sites. Two chemicals (1,1-DCE and 1,1,1-TCA) were not measured in groundwater samples. Boxplots show that chemicals have similar data range in subslab AFs and soil gas AFs. Less than 20% of PCE AFs and less than 50% of TCE AFs were NDs. However, other chemicals had high proportions of NDs or limited data (Figure 4). The KM method cannot accurately estimate percentiles of the chemicals other than PCE and TCE (Table 2).

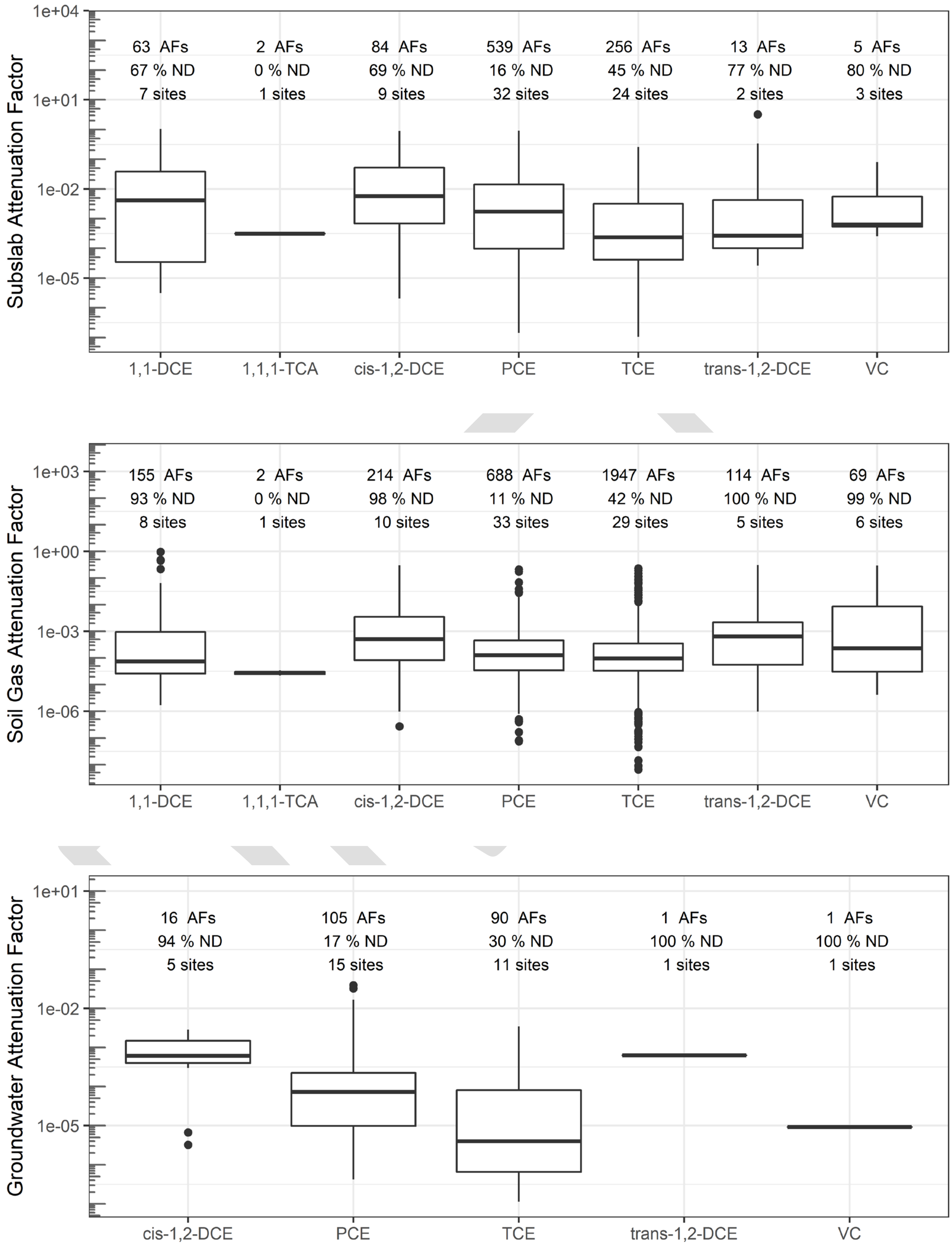


Figure 4. Boxplots of three types of attenuation factors on log10 scales by chemical.

Table 2. Percentiles of attenuation factors estimated by the Kaplan Meier method for seven chemicals.

Subset	Chemical	5th %tile	25th %tile	50th %tile	75th %tile	90th %tile	95th %tile
Subslab	1,1-DCE	3.16E-06	7.08E-06	1.61E-05	7.21E-05	5.56E-04	5.86E-03
Subslab	1,1,1-TCA	-	-	-	-	-	-
Subslab	cis-1,2-DCE	2.06E-06	9.49E-06	4.41E-05	7.00E-04	2.33E-03	1.42E-02
Subslab	PCE	4.25E-06	5.74E-05	8.20E-04	1.06E-02	4.50E-02	1.00E-01
Subslab	TCE	3.00E-07	1.11E-05	5.38E-05	2.38E-04	2.66E-03	4.81E-03
Subslab	trans-1,2-DCE	2.59E-05	2.59E-05	3.00E-05	6.48E-05	6.48E-05	6.48E-05
Subslab	VC	-	-	-	-	5.50E-03	5.50E-03
Soil gas	1,1-DCE	-	-	-	5.52E-06	2.08E-05	3.00E-05
Soil gas	1,1,1-TCA	2.18E-05	2.18E-05	-	-	-	-
Soil gas	cis-1,2-DCE	2.74E-07	2.74E-07	9.80E-07	9.80E-07	9.80E-07	2.48E-06
Soil gas	PCE	3.40E-06	2.41E-05	1.07E-04	4.04E-04	1.21E-03	2.92E-03
Soil gas	TCE	1.45E-08	9.85E-06	4.58E-05	1.38E-04	3.86E-04	8.09E-04
Soil gas	trans-1,2-DCE	-	-	-	-	-	-
Soil gas	VC	-	-	-	-	-	-
Groundwater	cis-1,2-DCE	3.25E-06	3.25E-06	3.25E-06	3.25E-06	3.25E-06	3.25E-06
Groundwater	PCE	6.82E-07	4.50E-06	6.25E-05	1.79E-04	1.01E-03	2.11E-03
Groundwater	TCE	3.03E-07	4.29E-07	1.22E-06	5.67E-05	1.19E-04	1.33E-04
Groundwater	trans-1,2-DCE	-	-	-	-	-	-
Groundwater	VC	-	-	-	-	-	-

AF summary by screening steps

Following the approach documented in the USEPA 2012 report, multiple steps of data screening were conducted to select subsets of data, which were used to summarize percentiles representing empirical subslab, soil gas, and groundwater AFs (USEPA, 2012). The data screening was conducted on the aggregate data of seven chemicals.

The starting dataset was called “Aggregate” and the data subset after each step of screening used the name of the screening step. Boxplots and density plots exhibit the data range and distribution pattern for each subset of data (Figure 4 – 6). Table 3 provides a summary and KM estimates of percentiles. All datasets had less than 50% NDs. Subslab, soil gas, and groundwater AFs had different data distributions.

Data screening may have helped to exclude AFs with high uncertainties in two categories:

[1] High level detections in C_{IA} with low C_S; and

[2] High level RLs in C_{IA} with low C_S.

In the first category, figures showed that data screening generally excluded high values of AFs and reduced the data variation (Figure 4A – 6A). According to the AF equation (eq. 1), high AFs may have relatively low C_S but high C_{IA}; thus sources other than subsurface vapor could contribute to these C_{IA}. It was possible that these high AFs did not represent the actual vapor intrusion well.

In the second category, the highest RLs declined post-data-screening, especially in subslab and soil gas AFs (Figure 4A – 6A). A RL of AF was calculated with a RL of C_{IA} and a quantifiable C_S. High RLs in AFs had great uncertainty because their C_{IA} were reported as NDs but had RLs higher than quantifiable detections in other samples.

Among all the screening steps, the screening “AF < 1” resulted in the smallest change from the “Aggregate” dataset. “IA > Bkgd” reduced the counts of data points from the “AF < 1” dataset by 60 – 76%, and its datasets comprised the fewest sites compared to other subsets of subslab, soil gas, and groundwater AFs, except for “GW > 5000 Bkgd” (Table 3). “IA > Bkgd” unnecessarily excluded some low values of AFs (Figure 4A – 6A). The percentage of NDs was the lowest in this subset.

Compared to the “Aggregate” and “AF < 1” dataset, source strength screens resulted in lower percentile estimates at all levels. The stronger source strength screening was (the higher the multiplier of the background concentration was), the lower the percentile estimates were (Table 3). Distributions of both subslab and groundwater AFs appeared to be bimodal (Figure 4B and Figure 6B). Screenings other than “AF < 1” tended to flatten the second peaks and reshaped the distributions. Because the vapor intrusion data were collected from multiple sites statewide in multiple studies with various RLs over 10 years, their statistics were not sufficient to determine the subsets that are the most representative of the empirical AFs. Based on professional judgement, DTSC selected the subslab subset “SS > 50X Bkgd”, the soil gas subset “SG > 50X Bkgd”, and the groundwater subset “GW > 100X Bkgd” used for the summary and further analysis.

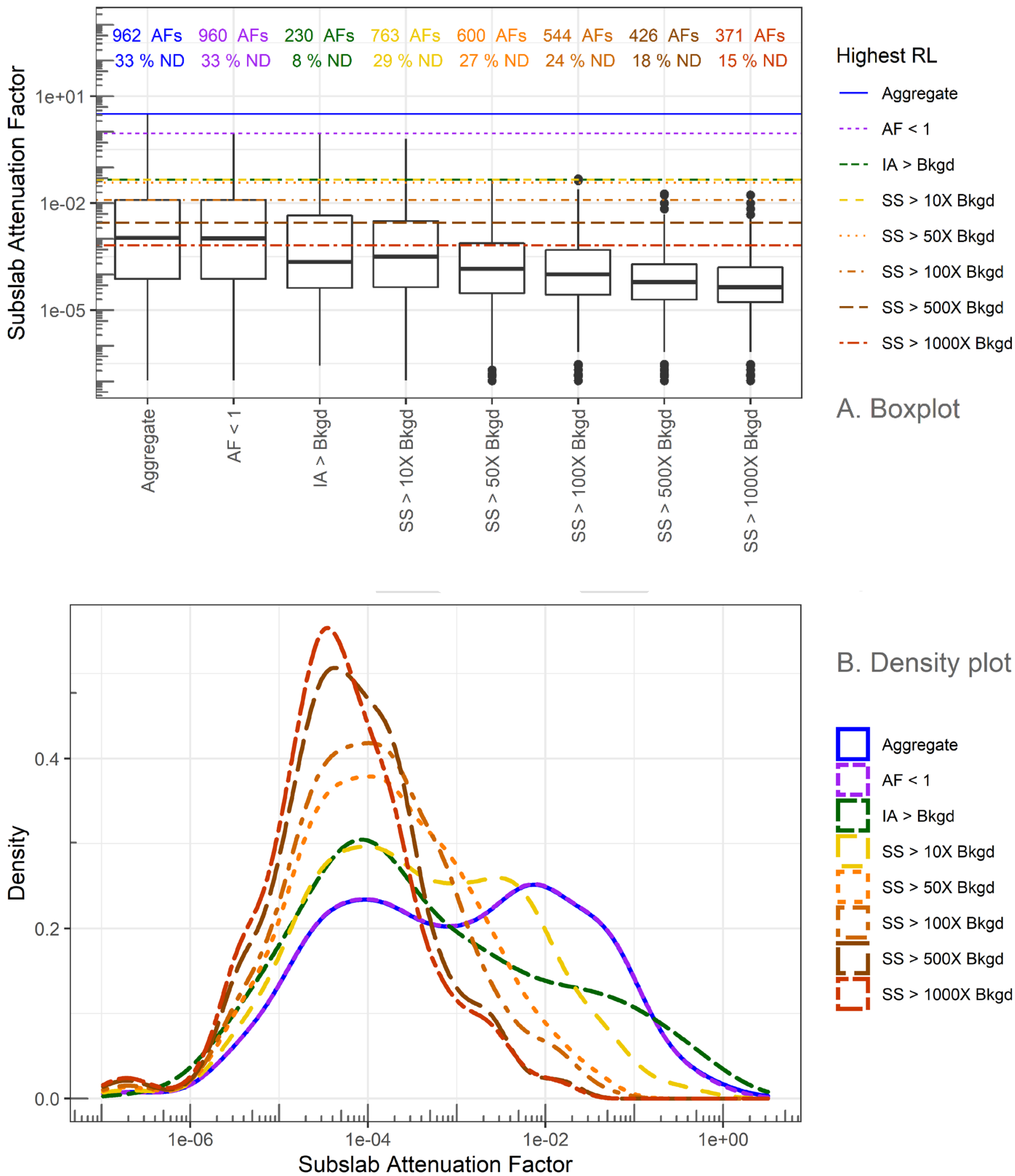
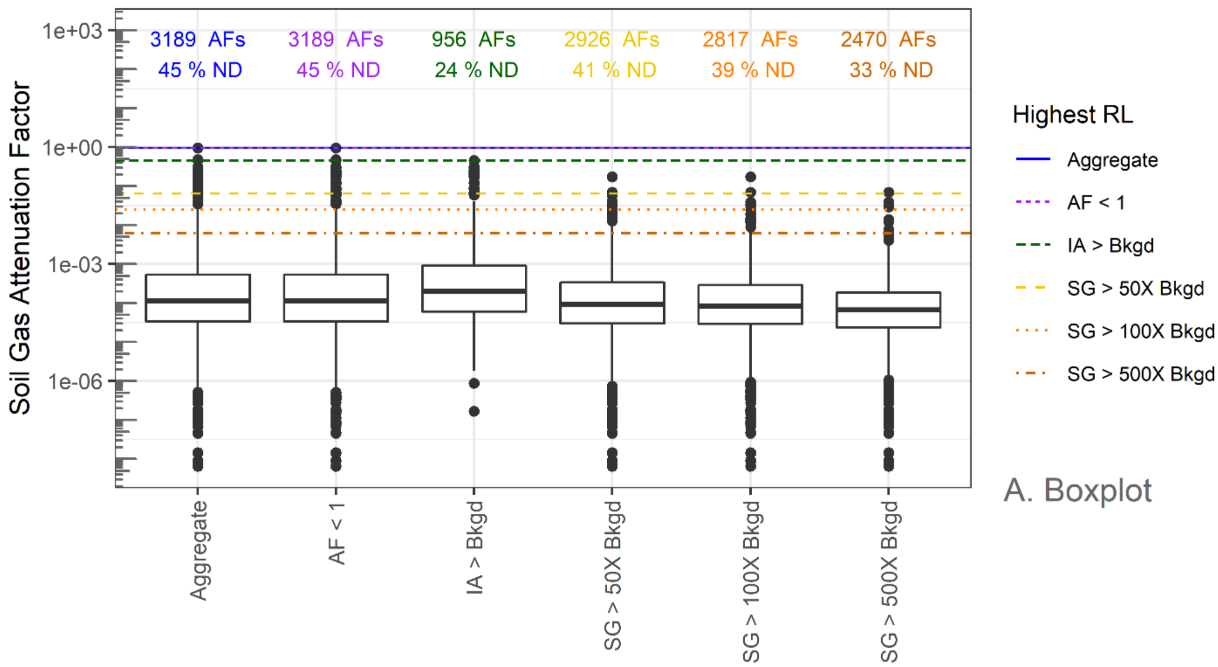


Figure 4. Distribution plots of subslab attenuation factor (AF) on log10 scale after each step of data screening. (RL = reporting limit of AF; IA = indoor air concentration; SS = vapor concentration in subslab)



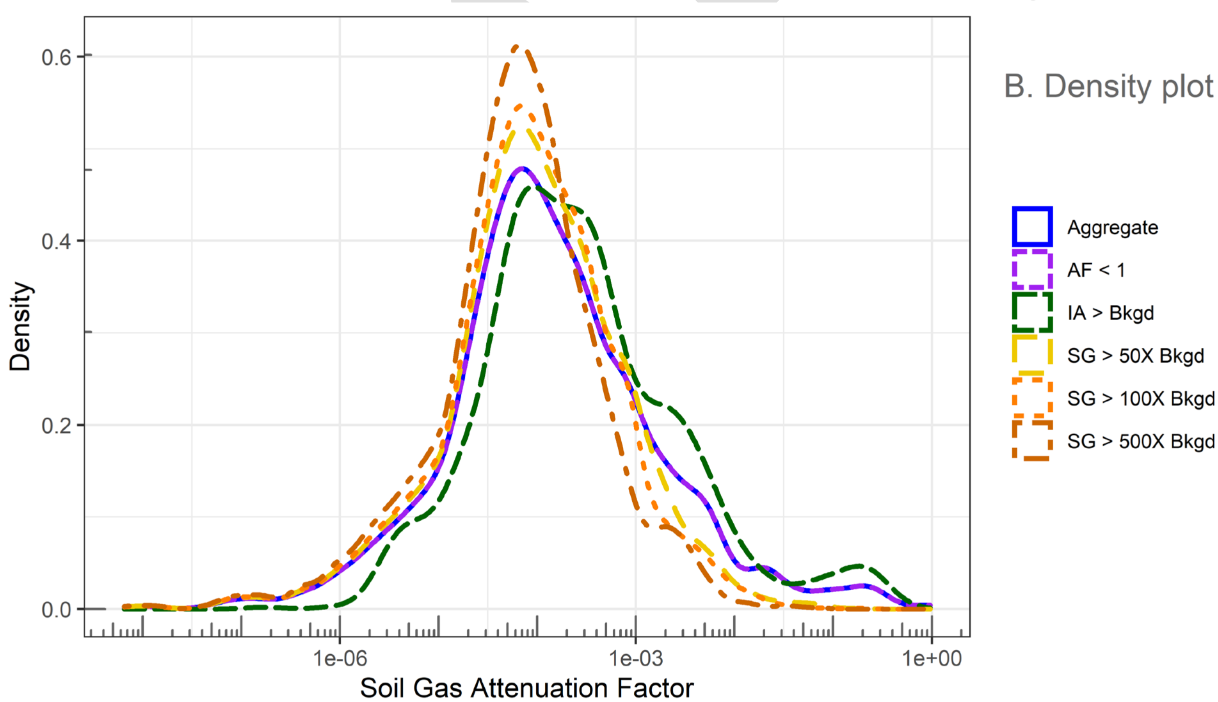


Figure 5. Distribution plots of soil gas attenuation factor (AF) on log10 scale after each step of data screening. (RL = reporting limit of AF; IA = indoor air concentration; GW = vapor concentration in soil gas)

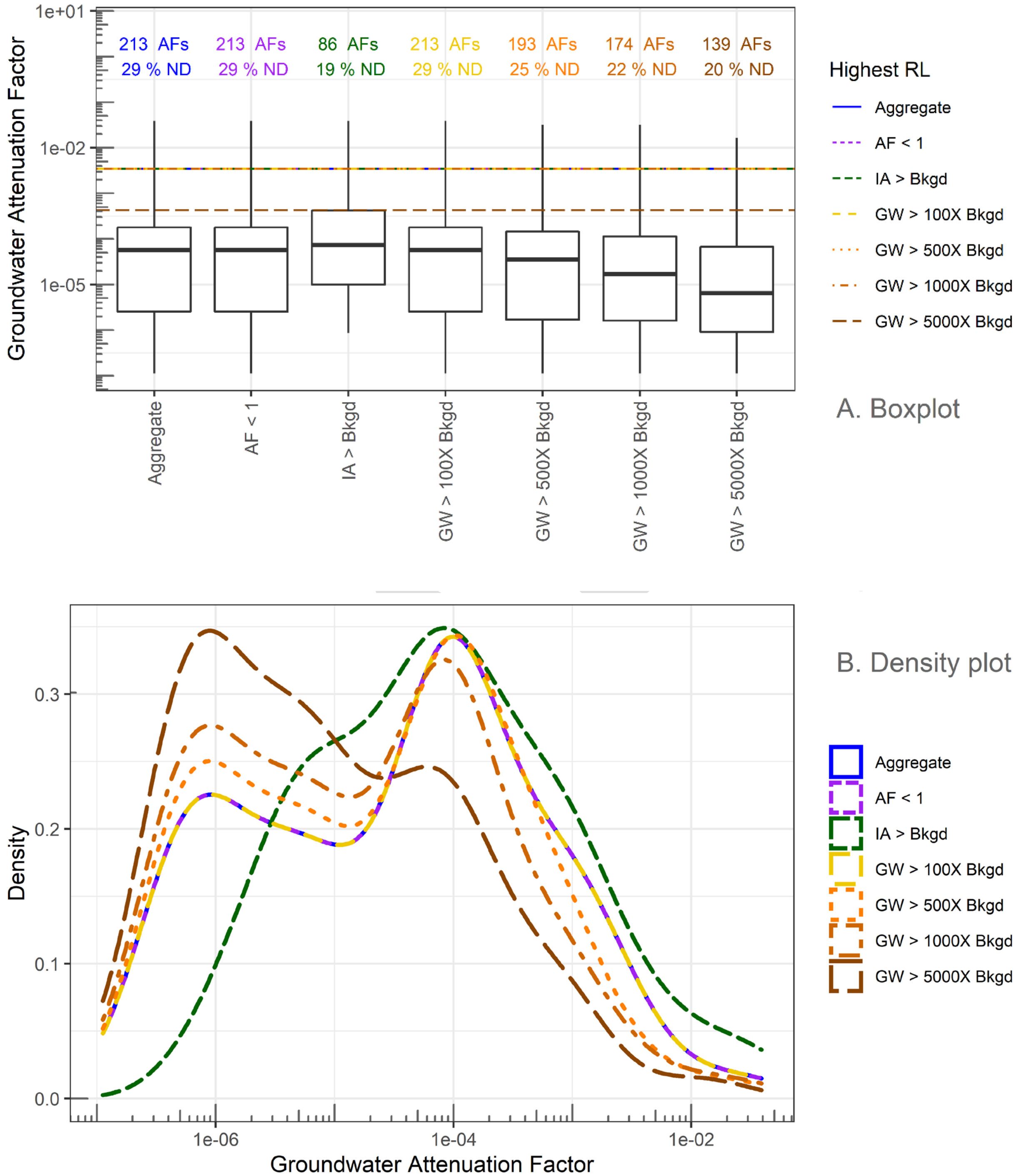


Figure 6. Distribution plots of groundwater attenuation factor (AF) on log10 scales after each step of data screening. (RL = reporting limit of AF; IA = indoor air concentration; GW = vapor concentration in groundwater)

Table 3. Percentiles of attenuation factors estimated by the Kaplan Meier method for each step of data screenings

Subset	Screening Step	Count of Sites	Count of AFs	ND%	50th %tile	75th %tile	90th %tile	95th %tile
Subslab	Aggregate	32	962	33	1.67E-04	3.69E-03	2.32E-02	6.00E-02
Subslab	AF < 1	32	960	33	1.67E-04	3.69E-03	2.32E-02	6.00E-02
Subslab	IA > Bkgd	26	230	8	1.67E-04	2.52E-03	6.00E-02	1.82E-01
Subslab	SS > 10X Bkgd	32	763	29	1.03E-04	1.37E-03	9.41E-03	2.47E-02
Subslab	SS > 50X Bkgd	32	600	27	6.67E-05	3.79E-04	2.33E-03	4.81E-03
Subslab	SS > 100X Bkgd	32	544	24	6.04E-05	2.62E-04	1.47E-03	3.15E-03
Subslab	SS > 500X Bkgd	32	426	18	4.42E-05	1.67E-04	6.74E-04	1.80E-03
Subslab	SS > 1000X Bkgd	30	371	15	3.92E-05	1.55E-04	5.98E-04	1.69E-03
Soil gas	Aggregate	35	3189	45	4.43E-05	1.57E-04	4.89E-04	1.04E-03
Soil gas	AF < 1	35	3189	45	4.43E-05	1.57E-04	4.89E-04	1.04E-03
Soil gas	IA > Bkgd	27	956	24	1.24E-04	3.80E-04	1.11E-03	2.62E-03
Soil gas	SG > 50X Bkgd	35	2926	41	4.34E-05	1.53E-04	4.61E-04	8.65E-04
Soil gas	SG > 100X Bkgd	35	2817	39	4.33E-05	1.50E-04	4.55E-04	8.33E-04
Soil gas	SG > 500X Bkgd	35	2470	33	4.19E-05	1.41E-04	4.11E-04	7.32E-04
Groundwater	Aggregate	16	213	29	1.33E-05	1.14E-04	3.62E-04	1.01E-03
Groundwater	AF < 1	16	213	29	1.33E-05	1.14E-04	3.62E-04	1.01E-03
Groundwater	IA > Bkgd	14	86	19	5.72E-05	2.24E-04	1.01E-03	6.68E-03
Groundwater	GW > 100X Bkgd	16	213	29	1.33E-05	1.14E-04	3.62E-04	1.01E-03
Groundwater	GW > 500X Bkgd	16	193	25	1.10E-05	1.14E-04	3.50E-04	1.01E-03
Groundwater	GW > 1000X Bkgd	16	174	22	9.58E-06	7.47E-05	2.24E-04	1.01E-03
Groundwater	GW > 5000X Bkgd	13	139	20	3.82E-06	5.72E-05	1.85E-04	1.01E-03

AF summary by building use types

DTSC selected the subslab dataset “SS > 50X Bkgd”, the soil gas dataset “SG > 50X Bkgd”, and the groundwater dataset “GW > 100X Bkgd” for further analysis. The analysis to summarize attenuation factors by building use types were performed on these datasets (Figure 7, Table 4).

There were fewer residential sites in the database than non-residential sites. In the selected subsets, residential data were from three sites for subslab AFs, six sites for soil gas AFs, and one site for groundwater AFs; non-residential data were from 30 sites for subslab, 32 sites for soil gas, and 15 sites for groundwater (Figure 7). This explained why the variation of the residential AFs was smaller than the non-residential AFs for all three types of subsurface media. Unequal sample sizes and variances can strongly reduce the power of statistical tests (Rusticus and Lovato, 2014); therefore, the results of the following comparison had limitations.

The Peto-Prentice test results showed that AFs of residential and non-residential sites had significantly different distributions (p-value: <2E-16 for subslab AF, 0.002 for soil gas AF, and 7E -13 for groundwater AF). Differences between residential and non-residential buildings varied across the three types of AFs. The median of subslab AFs of residential buildings was 45 times the median of non-residential buildings. For soil gas, the AF median of residential buildings was 1.6 times the median of non-residential buildings. The median of groundwater AF of residential sites was 1/100 of the median of non-residential. Residential data in the subslab dataset “SS > 50X Bkgd” had no AFs that were NDs. The highest RLs of NDs were close to the maximum quantifiable AFs in non-residential subslab, and in both non-residential and residential soil gas data.

Since the differences between residential and non-residential AFs in Figure 7 were similar to the two peaks in Figure 4B and 6B, density plots were generated for residential and non-residential AFs separately with the subset “AF < 1” and selected source strength screening sets (Figure 8). Figure 8 demonstrates that the bimodal distributions of subslab and groundwater AFs are mainly due to different distributions of residential and non-residential buildings. After data were categorized by building uses, the distributions were no longer bimodal. The two types of buildings had a closer data pattern in soil gas AFs, and therefore did not show bimodal pattern in their aggregate data. Figure 8 also shows how the selected source strength screenings smoothed the distributions for residential and non-residential data respectively in subslab and soil gas AFs.

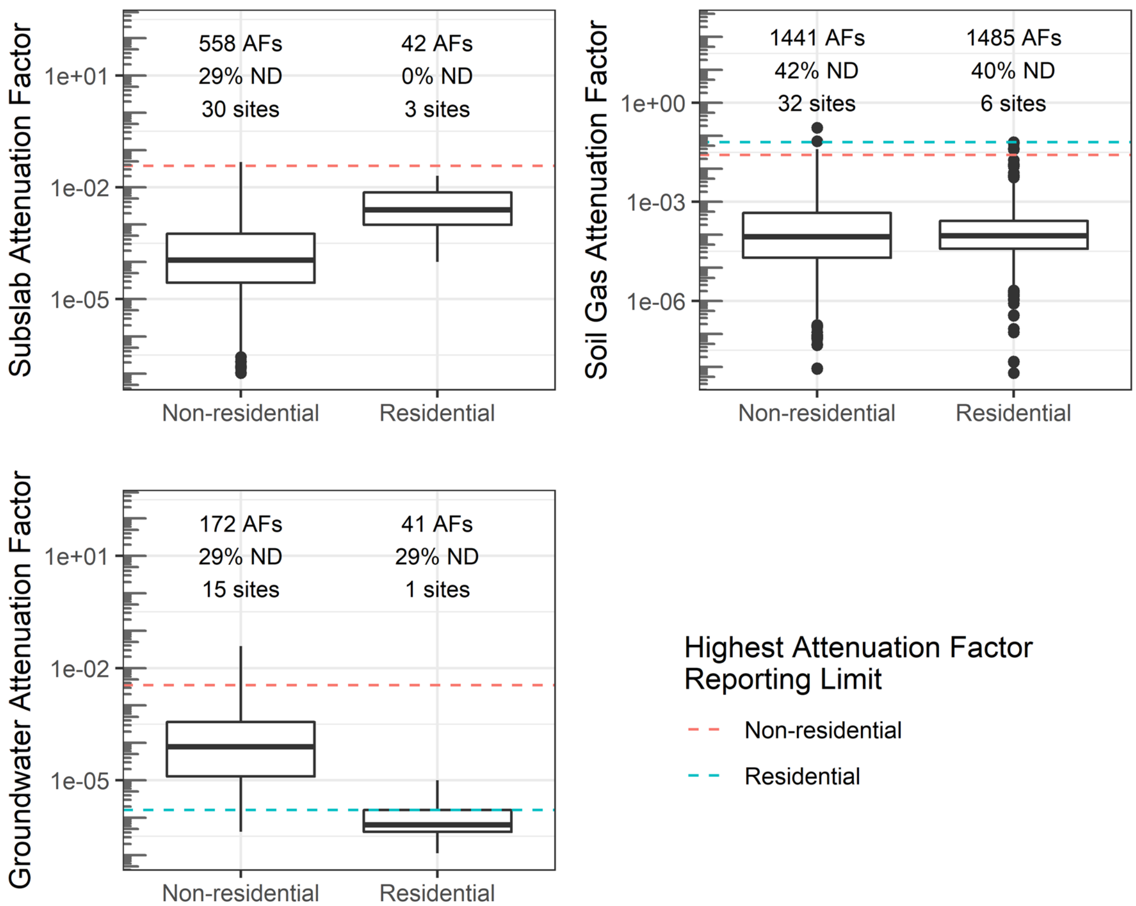


Figure 7. Boxplots of attenuation factors (AFs) on log10 scales by building use types for three types of subsurface vapor.

Table 4. Percentiles estimated by the Kaplan Meier method for attenuation factors by two types of building use.

Subset	Building Use Type	5th %tile	25th %tile	50th %tile	75th %tile	90th %tile	95th %tile
Subslab	Non-residential	2.30E-06	1.33E-05	5.56E-05	2.38E-04	1.16E-03	3.13E-03
Subslab	Residential	3.16E-04	9.88E-04	2.47E-03	7.33E-03	1.00E-02	1.80E-02
Soilgas	Non-residential	4.74E-08	3.40E-06	3.33E-05	1.61E-04	6.43E-04	1.63E-03
Soilgas	Residential	1.45E-08	1.73E-05	5.21E-05	1.41E-04	3.60E-04	5.71E-04
Groundwater	Non-residential	6.30E-07	2.53E-06	5.72E-05	1.33E-04	6.13E-04	1.61E-03
Groundwater	Residential	2.86E-07	3.75E-07	4.29E-07	8.67E-07	3.82E-06	8.93E-06

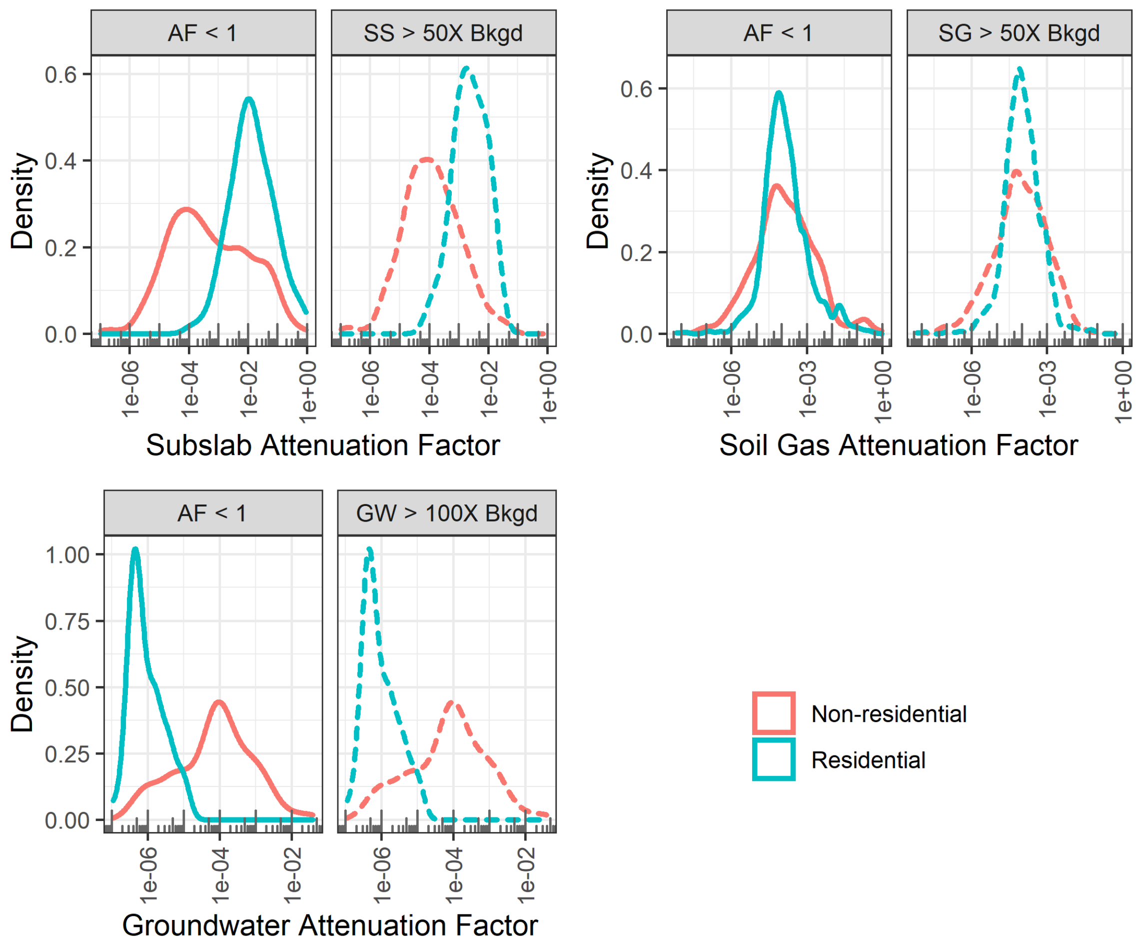


Figure 8. Density plots of attenuation factors (AFs) on log10 scales by building use types with screened datasets.

AF summary by sampling depths

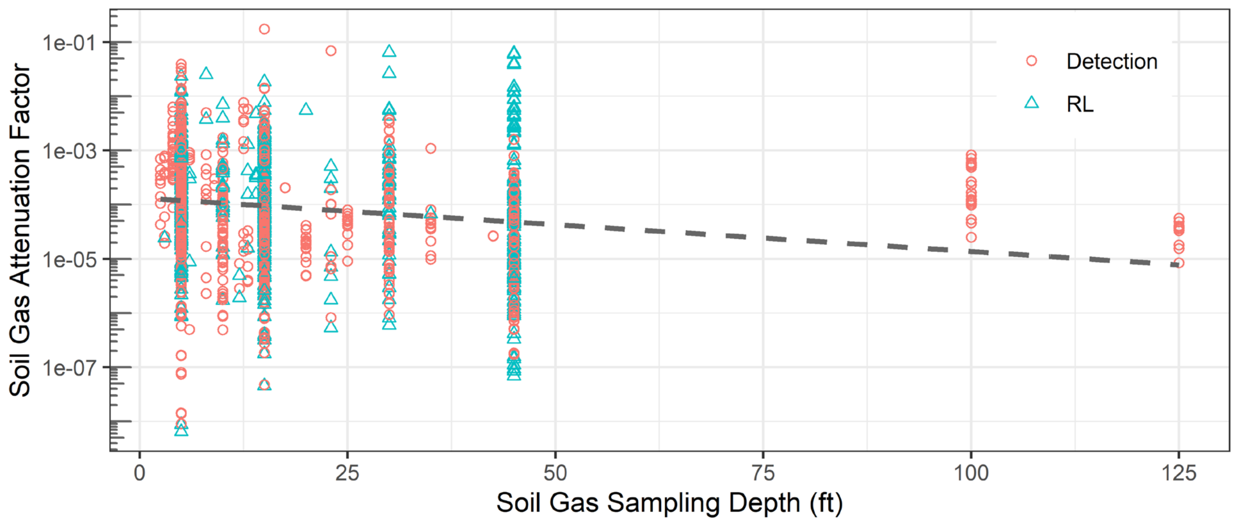
Analysis on the impact of sampling depths was conducted on the soil gas subset "SG > 50 Bkgd" and the groundwater subset "GW > 100 Bkgd" for records that have reported depths. This analysis was to summarize how attenuation factor values were distributed by sampling depths of soil gas and groundwater measurements. Figure 9 showed that the soil gas data were collected from soil depth of 2.5 to 125 ft and sample sizes varied at different depths. Of 35 sites in the soil gas dataset, 32 sites had samples at ≤ 10 ft, 28 sites had samples at 10 – 20 ft, and 11 sites had samples at > 20 ft (Table 5). In a total of 2908 soil gas AFs, 81% were calculated from soil gas concentrations collected at ≤ 20 ft. Data at deeper soil were limited and had large gaps. For example, there were no soil gas measurements at depths from 50 to 100 ft.

A total of 198 AFs were calculated from the groundwater measurements collected from depths of 4 to 52 ft. There were a total of 16 sites. Each of three depth groups within depths 0 – 40 ft contained data from 5 – 6 sites. Two sites provided measurements at depths > 40 ft.

These soil gas and groundwater numbers suggest that most studies collected subsurface data from limited depths. Because [1] the database aggregated data from multiple studies, [2] the used studies were not designed for balanced sampling, and [3] NDs with multiple high levels of RLs existed, the following analysis provided preliminary and exploratory results on the impact of sampling depth. Additional data collection and analysis are necessary to confirm the results.

Percentiles were summarized using the KM method for three depth groups of soil gas AFs (Table 5). AFs with sampling depth > 20 ft had high percentages of NDs so their estimates had high uncertainties. The increasing percentages of NDs may suggest that the AFs decreased with deeper sampling depth. The Peto-Prentice test result confirmed this observation with a p-value < 2E-16. The MLE result also showed that the geometric mean of soil gas AFs declined with the increased sampling depths. The slope was estimated at -0.04 with a p-value at 0. The slope of -0.04 meant that the geometric mean of AFs decreased by 49% with every 10 ft increase of sampling depth. However, the likelihood correlation coefficient r was low (0.24). The residuals of MLE did not meet the lognormal distribution assumption with a left skewed tail as shown in Figure 10. Therefore, the MLE slope cannot accurately quantify the relationship between soil gas AFs and sampling depths.

Groundwater data “GW > 100 Bkgd” had fewer data points and showed a different pattern from soil gas AFs (Figure 9). The MLE result estimated a likelihood r at 0.15. The slope was 0.03 with p-value of 0.03. The positive slope suggested that the geometric mean of AF values increased by 35% with every 10 ft increase of sampling depth. Figure 11 displays a residual plot with a distribution closer to log normal than Figure 10. The Peto-Prentice test showed that the three AF distributions at depths < 40 ft were not significantly different. Depths > 40 ft had significantly higher AF values than depths at 4 – 40 ft. These results suggested that the relationship between groundwater AFs and sampling depths were not linear. In addition, smaller sample sizes and variances of AFs at depths > 40 ft could have affected the test results. Data from more sites at deep sampling depth are needed to draw a conclusion on the relationship.



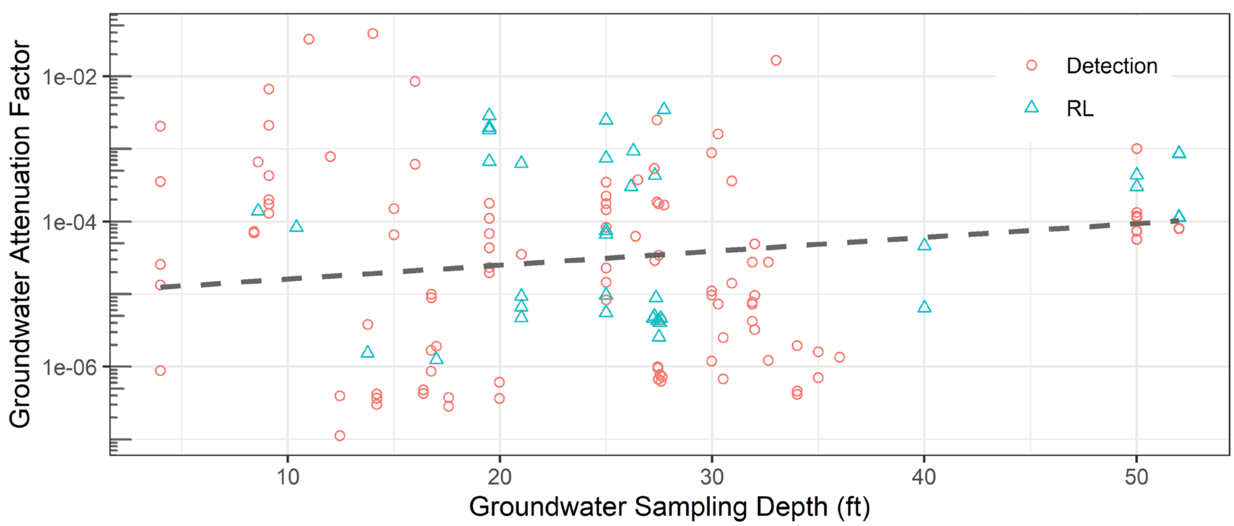


Figure 9. Scatterplot of attenuation factors on log10 scale and sampling depths of subsurface vapor. Data points of RL represent attenuation factors calculated from indoor air concentration originally reported as non-detects, but flagged and replaced with associated method detection limits or reporting limits in pre-processing.

Table 5. Summary of attenuation factors by groups of subsurface vapor sampling depths

Subset	Screen-ing	Depth Range	Count of Sites	Count of Depths	Count of AFs	ND %	50th %tile	75th %tile	90th %tile	95th %tile
Soil gas	SG > 50X Bkgd	≤10 ft	32	8	1334	32	1.00E-04	2.86E-04	6.55E-04	1.22E-03
Soil gas	SG > 50X Bkgd	10 - 20 ft	28	7	1036	42	3.81E-05	8.00E-05	2.44E-04	5.82E-04
Soil gas	SG > 50X Bkgd	>20 ft	11	8	538	64	3.35E-06	4.44E-05	1.59E-04	4.33E-04
Ground-water	GW > 100X Bkgd	≤ 15 ft	5	12	32	12	6.60E-05	3.57E-04	2.11E-03	3.24E-02
Ground-water	GW > 100X Bkgd	15 - 25 ft	6	10	57	35	8.93E-06	8.33E-05	2.24E-04	3.50E-04
Ground-water	GW > 100X Bkgd	25 - 40 ft	6	32	59	22	3.25E-06	2.90E-05	3.75E-04	1.61E-03
Ground-water	GW > 100X Bkgd	> 40 ft	2	2	50	30	7.95E-05	1.19E-04	1.33E-04	1.01E-03

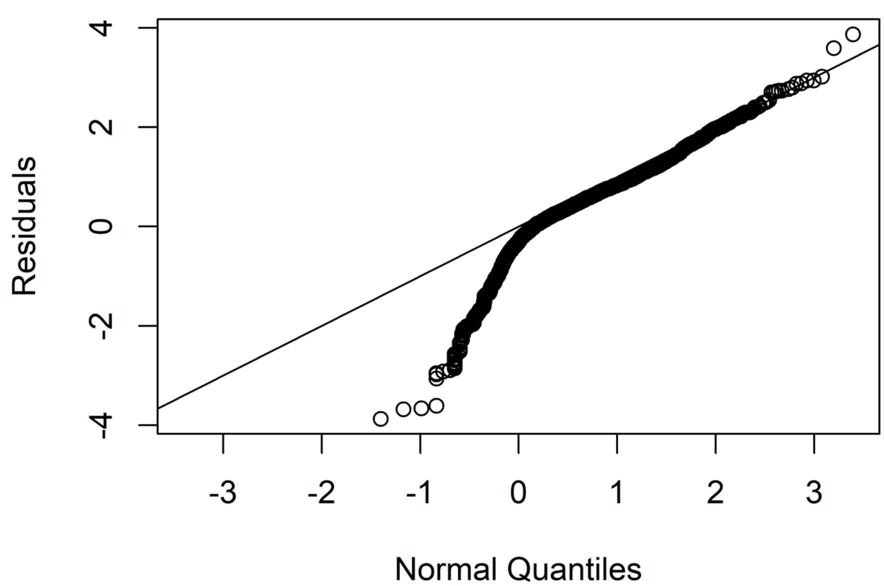


Figure 10. Residual Q-Q plot of Maximum Likelihood Estimate for soil gas attenuation factor and sampling depths.

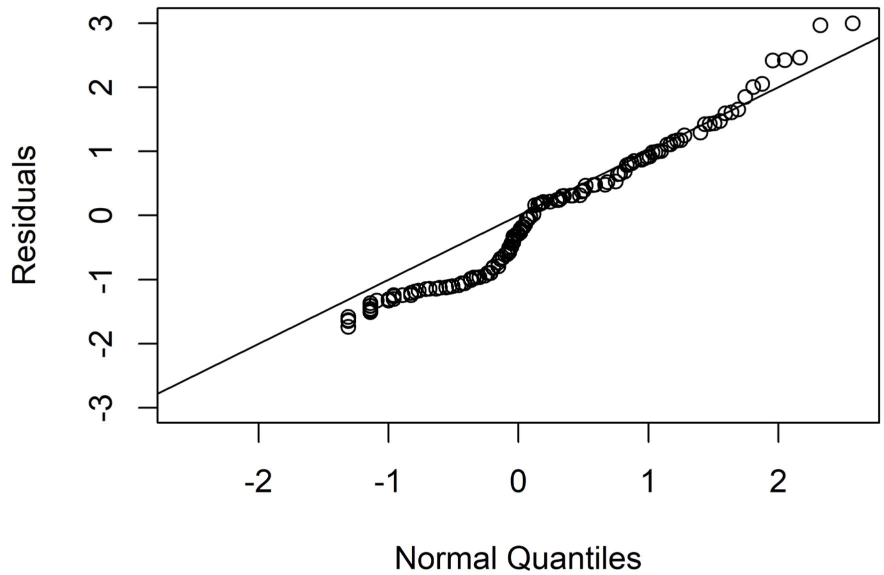


Figure 11. Residual Q-Q plot of Maximum Likelihood Estimate for groundwater attenuation factor and sampling depths.

AF summary by sampling distances

The analysis for the sampling distances also used the dataset “SG > 50 Bkgd” and “GW > 100 Bkgd” but only for the records with reported distances. This analysis was to summarize how AF values are distributed among subsurface samples from different distances away from the edges of the buildings. A total of 2343 soil gas AFs and 119 groundwater AFs with sampling distances were available for analysis. Figure 12 and MLE results suggested that there was no correlation between AF values and sampling distances of subsurface vapor. The Peto-Prentice test showed that groundwater AFs of two distance groups did not have different distributions. Soil gas AFs may distribute differently between samples in different distance ranges, but the change over the distance was not monotonic (Table 6). AFs of soil gas sampled at distances 10 – 25 ft and distances > 50 ft appeared to be generally higher than AFs of soil gas at distances ≤ 10 ft and 25 – 50 ft. Considering the data limitations and all the results, there was not enough evidence to reject the hypothesis that AF values were not different for samples collected at different distances to the buildings.

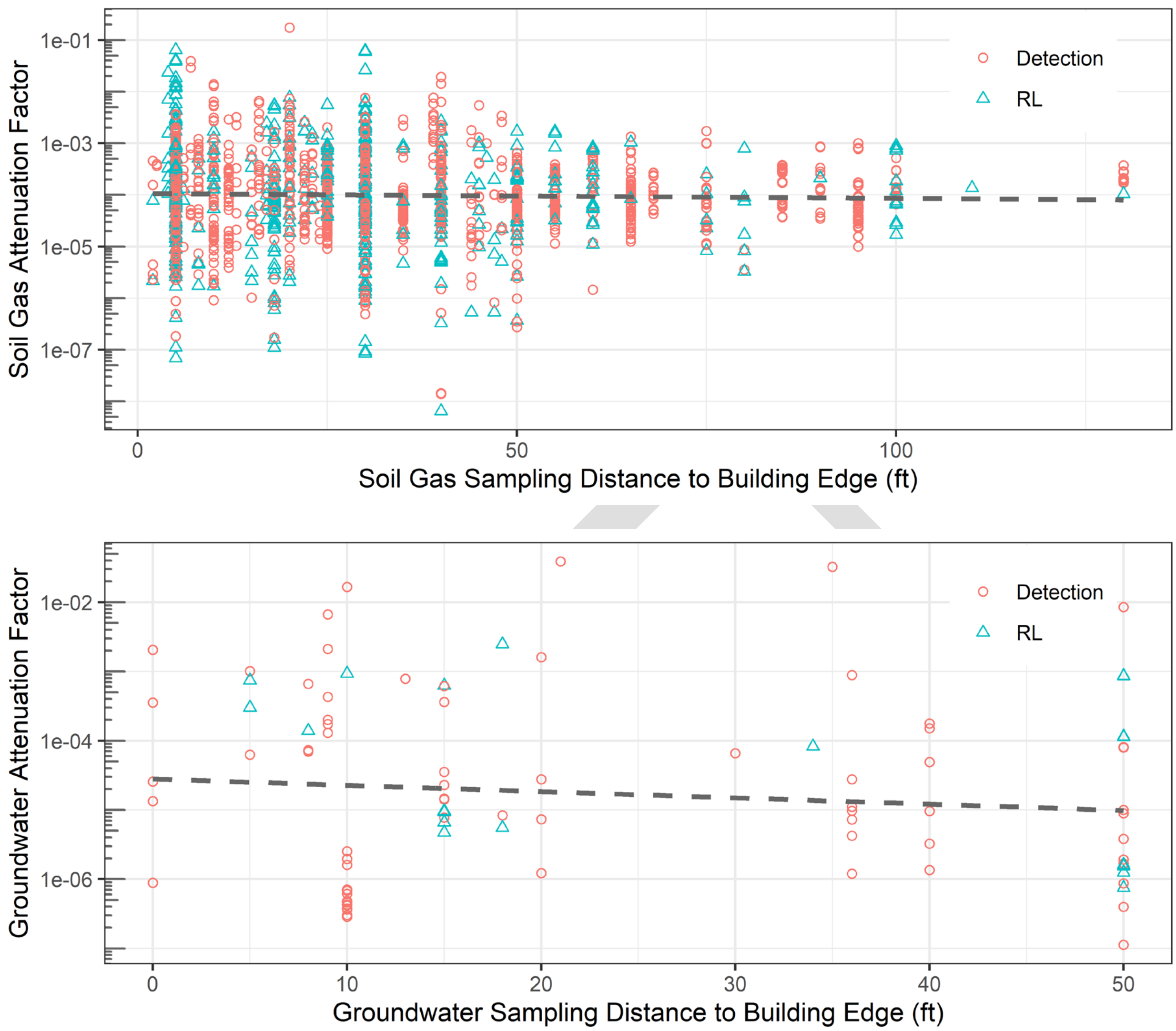


Figure 12. Scatterplot of attenuation factors on log10 scale and sampling distances of subsurface vapor. Data points of RL represent attenuation factors calculated from indoor air concentration originally reported as non-detects but flagged and replaced with associated method detection limits or reporting limits in the pre-processing.

Table 6. Summary of attenuation factors by groups of subsurface vapor sampling distances

Subset	Screen-ing	Distance Range	Count of Sites	Count of Distances	Count of AFs	ND%	50th %tile	75th %tile	90th %tile	95th %tile
Soilgas	SG > 50X Bkgd	≤ 10 ft	19	8	498	44	3.26E-05	2.32E-04	7.26E-04	1.28E-03
Soilgas	SG > 50X Bkgd	10 - 25 ft	15	11	526	35	6.75E-05	2.50E-04	5.87E-04	1.02E-03
Soilgas	SG > 50X Bkgd	25 - 50 ft	16	10	834	45	4.04E-05	1.23E-04	4.50E-04	8.02E-04
Soilgas	SG > 50X Bkgd	> 50 ft	2	12	485	41	5.56E-05	1.40E-04	3.02E-04	3.98E-04
Ground-water	GW > 100X Bkgd	< 25 ft	10	10	74	18	2.53E-06	1.74E-04	1.01E-03	2.11E-03
Ground-water	GW > 100X Bkgd	> 25 ft	6	6	45	31	3.82E-06	1.10E-05	1.52E-04	8.83E-04

Summary and Discussion

The DTSC VI database provides current and comprehensive VI data for CVOCs and represents VI conditions commonly found in California. This report documents the procedure to estimate media-specific AF percentiles after a series of data screenings. In addition, the report presents the impact of three variables (building use, sampling depth, and sampling distance) on the calculated AFs. DTSC (2020) used the estimations of this analysis to determine California empirical AFs and provided an understanding of the technical aspects of VI. Results showed that residential and non-residential buildings had significantly different AF distributions, especially for subslab and groundwater data. The sampling depths of subsurface measurements could have affected their estimated AFs. The AF differences between building types and between sampling depths were not constant across subsurface media. There was no significant difference for AFs of subsurface data sampled from various lateral distances to buildings.

The data and the analysis documented in this report have limitations. In the database, indoor air concentrations and subsurface vapor were usually not sampled on the same day. Two concentrations measured within a period of three months may be paired to calculate AFs. This pairing method may affect the AFs and affect the relationship between AFs and their impact factors. NDs of the data limited the statistical methods that can be applied in the analysis. The comparison for AFs by various groups was preliminary because of unequal sample sizes and variances. This analysis has not considered the possible effect of two types of buildings on the relationship between AFs and sampling locations. The random effect of individual sites and buildings and other impact factors such as sampling season and region have not been evaluated.

Comparison of summary methods

Similar to the USEPA 2012 report, this analysis used the Kaplan-Meier method to estimate percentiles of attenuation factors. This method has limitations: as an non-parametric method, KM estimates percentiles based on the data points' rank scores. It cannot count NDs that have RLs higher than all the detections or quantifiable values. Figure 13 compares the KM estimates in Table 3 with the results of two other methods (MLE and ROS with the assumption of a log normal distribution) reported in Helsel (2012) and two traditional subsitution approaches (subsituting NDs with RL/2 or RL then perform regular summary). SUB1 method used RL/2 to replace NDs and was commonly used in the analysis of environmental data. SUB2 method used RLs, the highest possible values of NDs, to summarize percentiles; therefore, it tended to overestimate. SUB2 results were considered to be the upper limits of all the statistics. The differences between SUB1 and SUB2 estimates for the 50^{th} – 95^{th} percentiles reflected that NDs in AF data were not low values (Figure 13). Their RL values were calculated from RLs of indoor air concentrations and quantifiable subsurface vapor concentrations. Some calculated limits were higher than 75% of subslab AFs and 95% of soil gas and groundwater AFs. These high level RLs caused uncertainties in all the estimations.

Figure 13 shows that KM, MLE, and ROS generally produced estimates lower than subsitution approaches. KM estimated some unusual 95^{th} percentiles for the subslab and groundwater datasets after the screening "IA > Bkgd". This may be because that KM is a type of survival analysis and it has approach different from traditional percentile estimation when handling ties (multipe observations at the same level) in detections (Helsel, 2012). The estimates of all the methods become more similar after source strength screenings eliminate some NDs with high RLs.

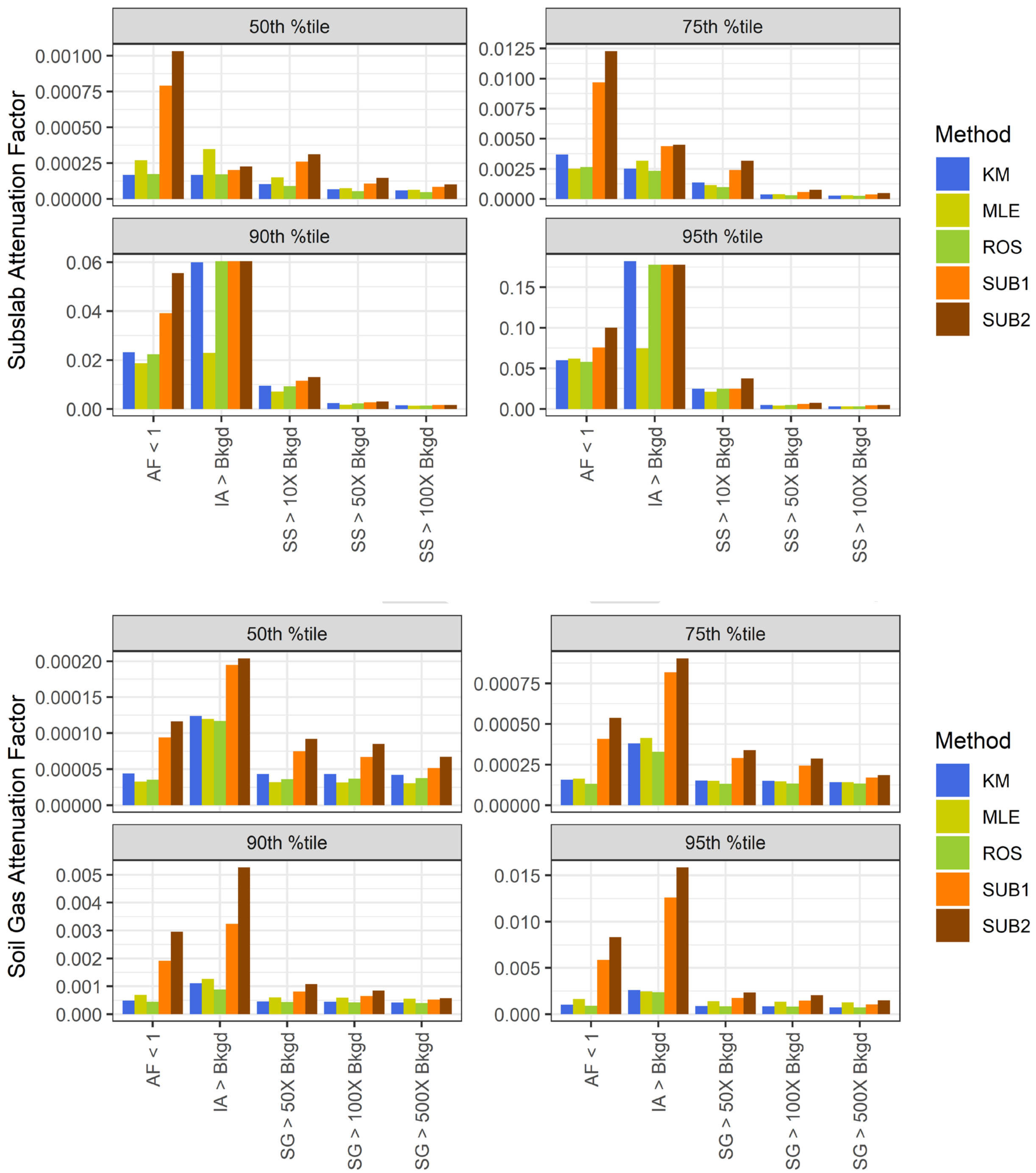


Figure 13. Comparison of percentiles summarized by different approaches for selected data screening subsets. (KM: Kaplan-Meier; MLE: Maximum Likelihood Estimate; ROS: Regression on Order Statistics; SUB1: regular percentiles with non-detects substituted by half values of reporting limits; SUB2: regular percentiles with non-detects substituted by values of reporting limits.)

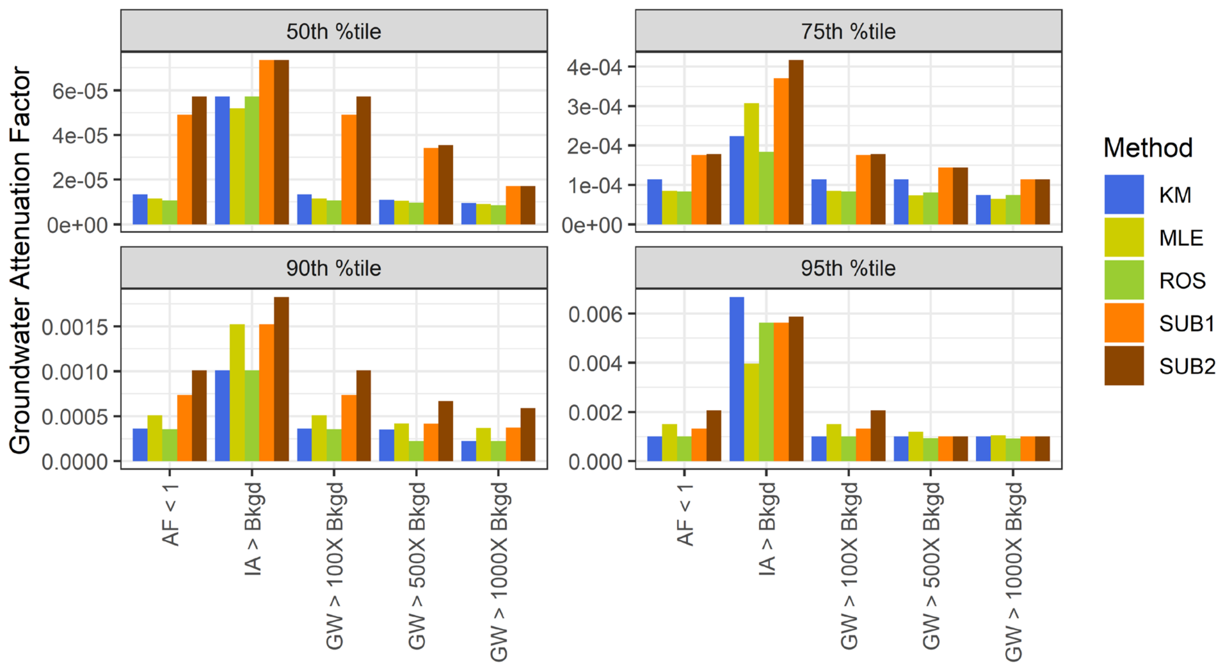


Figure 13 (cont.). Comparison of percentiles summarized by different approaches for selected data screening subsets. (KM: Kaplan-Meier; MLE: Maximum Likelihood Estimate; ROS: Regression on Order Statistics; SUB1: regular percentiles with non-detects substituted by half values of reporting limits; SUB2: regular percentiles with non-detects substituted by values of reporting limits.)

Suggestions for future analysis

For future studies, it may be necessary to structure the database as individual tables of site information, building information, subslab samples, soil gas samples, groundwater samples, indoor samples, and outdoor samples. All the tables should be related by unique site, building, and sample identifiers. Using relational tables, it is easy to perform quality control and assessment on the data inputs. The analysis for the concentration measurements can be properly conducted by extracting data from concentration tables, instead of the current table structured to analyze AFs. For the analysis of attenuation factors, the different pairing methods of indoor and subsurface data can be evaluated with the consideration of sampling month or season. If additional sampling to collect more data is possible, a statewide study with a balanced sampling design (similar sampling size for all combinations of site, building, and sampling conditions) and a consistent laboratory reporting limit may provide data to improve this analysis. A multivariate analysis or mixed effects modeling may be applied to analyze the relationship of AFs or concentrations and multiple variables of sites, buildings, and sampling conditions. The R package “NADA” developed to implement the methods reported in Helsel (2012) and used in this analysis does not provide functions to perform multivariate analysis or fit mixed effects models. A strategically statistical approach needs to be researched, developed, and evaluated to implement these analyses for the data with highly diverse levels of reporting limits and without the proper assumption of a distribution (such as the VI data).

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Reference

[DTSC] Department of Toxic Substances Control. DTSC's Vapor Intrusion Database: Evaluation of Attenuation Factors for Buildings in California. California Environmental Protection Agency, Department of Toxic Substances Control.

Helsel D. 2005. Nondetects and Data Analysis, Statistics for Censored Environmental Data. John Wiley & Sons, Inc., Hoboken, New Jersey.

Helsel D. 2012. Statistics for Censored Environmental Data using MINITAB and R (2nd ed.). John Wiley & Sons, Inc., Hoboken, New Jersey.

Lee L. 2017. NADA: Nondetects and Data Analysis for Environmental Data. R package version 1.6-1. https://CRAN.R-project.org/package=NADA.

R Core Team. 2019. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria; Website: https://www.R-project.org.

Rusticus, S. & Lovato, C. 2014. Impact of Sample Size and variability on the Power and Type I Error Rates of Equivalence Tests: A Simulation Study. *Practical Assessment, Research & Evaluation. Vol. 19, No. 11. August.*

[USEPA] United States Environmental Protection Agency. 2012. EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings. Office of Solid Waste and Emergency Response, Publication EPA 530-R-10-002.

Wickham H. 2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

Appendix: Example of R Code

1. Pre-processing

```
library(dplyr)
library(knitr)
library(stringr)
library(kableExtra)
```

read in data and check

```
data <- read.csv(VI.data, na.strings = c("", "NA"), stringsAsFactors = FALSE)
data2 <- data %>%
  select(site_name, site_id, site_city, site_type, chem_name, #site
         bldg_name, bldg_height, bldg_footprint, bldg_use, bldg_spacetype, bldg_hvac, #bldg
         subslab_id, subslab_date, subslab_conc, distance_subslab_indoor, #subslab
         soilgas_id, soilgas_date, soilgas_loc1, soilgas_loc2, distance_soilgas_bldg,
         distance_soilgas_indoor, soilgas_depth, soilgas_conc, #soilgas
         gdw_id, gdw_date, gdw_loc1, distance_gdw_bldg, distance_gdw_indoor, gdw_depth, gdw_soilgas_conc, #ground
water
         indoor_id, indoor_date, indoor_conc, indoor_mdl, indoor_rl ) %>% tibble::rowid_to_column() %>%
  mutate(subslab_date = as.Date(subslab_date, format = "%m/%d/%Y"),
         soilgas_date = as.Date(soilgas_date, format = "%m/%d/%Y"),
         gdw_date = as.Date(gdw_date, format = "%m/%d/%Y"),
         indoor_date = as.Date(indoor_date, format = "%m/%d/%Y"))
```

check site

```
#code unique site_name with an identifer as site_myid
site_name <- unique(data2$site_name)
sitecode <- data.frame(site_name, site_myid = 1:length(site_name))
data2 <- merge(data2, sitecode)
write.csv(sitecode, paste(path_export, "DTSC_VI_SITECODE.csv"), row.names = FALSE)
```

correct values

```
data2 <- data2 %>%
  mutate(
    site_city = str_to_title(site_city),
    #subslab: correct id, convert concentration and distance to numeric
    subslab_id = gsub(",", "", subslab_id),
    subslab_conc2 = as.numeric(gsub(",", "", subslab_conc)),
    distance_subslab_indoor = as.numeric(distance_subslab_indoor),

    #soilgas: correct loc, depth, and distance variable, convert concentration to numeric
    soilgas_loc1 = str_to_title(soilgas_loc1),
    soilgas_loc2 = ifelse(soilgas_loc2 == "Unknown", NA, str_to_title(soilgas_loc2)),
    #soilgas_depth = as.numeric(gsub("-split| \\(2)*", "", soilgas_depth)),
    distance_soilgas_bldg = as.numeric(gsub("ft", "", distance_soilgas_bldg)),
    distance_soilgas_indoor  = ifelse(distance_soilgas_indoor == "Unknown", NA,
                                       as.numeric(distance_soilgas_indoor)),
    soilgas_conc2 = as.numeric(gsub(",", "", soilgas_conc)),

    #groundwater: correct depth and distance variable, convert concentration to numeric
    gdw_depth = as.numeric(gdw_depth),
    distance_gdw_indoor = as.numeric(distance_gdw_indoor),
    gdw_conc2 = ifelse(as.numeric(gdw_soilgas_conc) > 0, as.numeric(gdw_soilgas_conc), NA),

    #indoor: correct mdl and rl and create nd flag
    indoor_mdl = as.numeric(indoor_mdl), #remove all texts
    indoor_rl = as.numeric(indoor_rl), #remove all texts
    nd_flag = ifelse(grepl("^\\d+",indoor_conc), FALSE,
                     ifelse(!(is.na(indoor_conc)), TRUE, NA)), #flag ND
    indoor_conc2 = ifelse(grepl("^\\d+",indoor_conc), as.numeric(indoor_conc),
                          ifelse(!(is.na(indoor_conc)) & !is.na(indoor_mdl),
                                 indoor_mdl, indoor_rl)),

    #calculate afs
    subslab_af = indoor_conc2/subslab_conc2,
    soilgas_af = indoor_conc2/soilgas_conc2,
    gdw_af = indoor_conc2/gdw_conc2) %>%
  #filter(!is.na(indoor_conc2) & !is.na(chem_name)) %>%
  select(rowid, site_name, site_myid, site_city, site_type, chem_name,
         bldg_myid, bldg_name, bldg_height2,bldg_footprint2, bldg_use, bldg_spacetype, bldg_hvac2,
         subslab_id, subslab_date, distance_subslab_indoor, subslab_conc2, subslab_af,
         soilgas_id, soilgas_date, soilgas_loc1, soilgas_loc2, distance_soilgas_bldg,
         distance_soilgas_indoor, soilgas_depth, soilgas_conc2, soilgas_af,
         gdw_id, gdw_date, gdw_loc1, gdw_depth, distance_gdw_bldg, distance_gdw_indoor,
         gdw_conc2, gdw_af, indoor_id, indoor_date,indoor_conc2, indoor_mdl, indoor_rl,
         nd_flag)

#chemname.miss <- data2%>% filter(is.na(chem_name))
indoor.na <- data2 %>% filter(is.na(indoor_conc2))%>%
  mutate(rowid=rowid+1)
#exclude <- unique(rbind(chemname.miss, indoor.na))

data2 <- data2 %>% filter(!is.na(indoor_conc2))
cat(paste("Original dataset have", nrow(data), "obs;"))
```

```
## Original dataset have 4821 obs;
```

```
cat(paste("Excluding NA indoor concentrations, there are", nrow(data2), "obs exported for further analysis."))
```

```
## Excluding NA indoor concentrations, there are 4761 obs exported for further analysis.
```

```
#output VI.data.processed
write.csv(data2, paste(path_export, "DTSC_VI_Processed.csv"), row.names = FALSE)
```

seperate AFs

```
#read in preprocessed VI data
VIdata <- read.csv(VI.data.processed, stringsAsFactors = FALSE) %>%
    mutate(subslab_date = as.Date(subslab_date, format = "%Y-%m-%d"),
           soilgas_date = as.Date(soilgas_date, format = "%Y-%m-%d"),
           gdw_date = as.Date(gdw_date, format = "%Y-%m-%d"),
           indoor_date = as.Date(indoor_date, format = "%Y-%m-%d"))
#excluding radon
radon.n <- nrow(VIdata %>% filter(chem_name == "Radon"))
VIdata <- VIdata %>% filter(chem_name != "Radon")

#summary how many invalid afs
exclude <- VIdata %>% filter(is.na(subslab_af) & is.na(soilgas_af) & is.na(gdw_af)) %>%
  mutate(rowid = rowid + 1)
invalidaf.n <- nrow(exclude)

#select valid afs for subslab, soil gas, and groundwater
subslab <- VIdata %>% filter(!is.na(subslab_af)) %>%
  select(rowid, site_name, site_myid, site_city, site_type, chem_name, bldg_name,
         bldg_height2,bldg_footprint2, bldg_use, bldg_spacetype, bldg_hvac2, bldg_myid,
         subslab_id, subslab_date, distance_subslab_indoor, subslab_conc2, af = subslab_af,
         indoor_id, indoor_date,indoor_conc2, indoor_mdl, indoor_rl,
         nd_flag) %>%
  mutate(date_diff = as.numeric(subslab_date - indoor_date),
         subset = "Subslab")

soilgas <- VIdata %>% filter(!is.na(soilgas_af)) %>%
   select(rowid, site_name, site_myid, site_city, site_type, chem_name, bldg_name,
         bldg_height2,bldg_footprint2, bldg_use, bldg_spacetype, bldg_hvac2, bldg_myid,
         soilgas_id, soilgas_date, soilgas_loc1, soilgas_loc2, distance_soilgas_bldg,
         distance_soilgas_indoor, soilgas_depth, soilgas_conc2, af= soilgas_af,
         indoor_id, indoor_date,indoor_conc2, indoor_mdl, indoor_rl,
         nd_flag)%>%
  mutate(date_diff = as.numeric(soilgas_date - indoor_date),
         subset = "Soilgas")

gdw <- VIdata %>% filter(!is.na(gdw_af)) %>%
   select(rowid, site_name, site_myid, site_city, site_type, chem_name, bldg_name,
         bldg_height2,bldg_footprint2, bldg_use, bldg_spacetype, bldg_hvac2, bldg_myid,
         gdw_id, gdw_date, gdw_loc1, gdw_depth, distance_gdw_bldg, distance_gdw_indoor,
         gdw_conc2, af = gdw_af,
         indoor_id, indoor_date,indoor_conc2, indoor_mdl, indoor_rl,
         nd_flag)%>%
  mutate(date_diff = as.numeric(gdw_date - indoor_date),
         subset = "Groundwater")
```

2. Functions for data screening and summary

```
screensum.fun <- function(data){
  step.name <- data$step[1]
  limit <- data %>% filter(nd_flag == 1) %>%
    summarize(af_rl_highest = max(af), n_nd = n())
  #SUB2
  summary <- data %>%
    summarize(n = n(),
              n.site = n_distinct(site_myid),
              n_gtrl = sum(nd_flag == 0 & af > limit$af_rl_highest),
              pct50_RL = median(af),
              pct75_RL = quantile(af, 0.75),
              pct90_RL = quantile(af, 0.9),
              pct95_RL = quantile(af, 0.95)) %>%
    cbind(limit) %>%
    mutate(per_nd = ifelse(is.na(n_nd), 0, round(n_nd/n * 100)),
           label = paste(n, " pairs\n", per_nd, "% ND\n"),
           label = ifelse(is.na(n_gtrl), label, paste(label, n_gtrl, "> highest rl")),
           step = step.name)
  #SUB1
  summary2 <- data %>%
    mutate(af2 = ifelse(nd_flag == 1, af/2, af)) %>%
    summarize(pct50_RL2 = median(af2),
              pct75_RL2 = quantile(af2, 0.75),
              pct90_RL2 = quantile(af2, 0.9),
              pct95_RL2 = quantile(af2, 0.95))
  summary <- cbind(summary, summary2)
  #KM
  KM <- with(data, cenfit(af, nd_flag))
  KM_pct <- quantile(KM, c(0.5, 0.75, 0.9, 0.95))
  names(KM_pct) <- c("KMpct50","KMpct75","KMpct90","KMpct95")
  summary <- cbind(summary, t(KM_pct))
  #MLE
  MLE <- with(data, cenmle(af, nd_flag))
  MLE_pct <- quantile(MLE, c(0.5, 0.75, 0.9, 0.95))
  names(MLE_pct) <- c("MLEpct50","MLEpct75","MLEpct90","MLEpct95")
  summary <- cbind(summary, t(MLE_pct))
  #ROS
  ROS <- with(data, cenros(af, nd_flag))
  ROS_pct <- quantile(ROS, c(0.5, 0.75, 0.9, 0.95))
  names(ROS_pct) <- c("ROSpct50","ROSpct75","ROSpct90","ROSpct95")
  summary <- cbind(summary, t(ROS_pct))

  return(summary)
}
```

```
datascreen.fun <- function(data){
  bkgd <- 1.36
  subset.name <- data$subset[1]

  ###Step0: Aggregate data info
  step.name = "Aggregate"
  data0 <- data %>% mutate(step = step.name)
  sum.step0 <- screensum.fun(data0)

  ###Step 1: af < 1
  step.name = "AF < 1"
  data1 <- data0 %>% filter(af <1) %>% mutate(step = step.name)
  sum.step1 <- screensum.fun(data1)

  ###Step 2a: indoor screening
  step.name = "IA > Bkgd"
  data2a <- data1 %>% filter(indoor_conc2 > bkgd) %>% mutate(step = step.name)
  sum.step2a <- screensum.fun(data2a)

  ###Step 2b: source strength screening: SS > 10X bkgd, SG > 50X bkgd, GW > 100X bkgd
  if(subset.name == "Subslab") {
    step.name = "SS > 10X Bkgd"
    data2b <- data1 %>% filter(subslab_conc2 > 10*bkgd) %>% mutate(step = step.name)
    } else if(subset.name == "Soilgas") {
      step.name = "SG > 50X Bkgd"
      data2b <- data1 %>% filter(soilgas_conc2 > 50*bkgd) %>% mutate(step = step.name)
    } else if(subset.name == "Groundwater") {
      step.name = "GW > 100X Bkgd"
      data2b <- data1 %>% filter(gdw_conc2 > 100*bkgd) %>% mutate(step = step.name)
    }
  sum.step2b <- screensum.fun(data2b)

  ###Step 2c: source strenth screening: SS > 50X bkgd, SG > 100X bkgd, GW > 500X bkgd
  if(subset.name == "Subslab") {
    step.name = "SS > 50X Bkgd"
    data2c <- data1 %>% filter(subslab_conc2 > 50*bkgd) %>% mutate(step = step.name)
    } else if(subset.name == "Soilgas") {
      step.name = "SG > 100X Bkgd"
      data2c <- data1 %>% filter(soilgas_conc2 > 100*bkgd) %>% mutate(step = step.name)
    } else if(subset.name == "Groundwater") {
      step.name = "GW > 500X Bkgd"
      data2c <- data1 %>% filter(gdw_conc2 > 500*bkgd) %>% mutate(step = step.name)
    }
  sum.step2c <- screensum.fun(data2c)
```

```
  ###Step 2d: source strenth screening: SS > 100X bkgd, SG > 500X bkgd, GW > 1000X bkgd
  if(subset.name == "Subslab") {
    step.name = "SS > 100X Bkgd"
    data2d <- data1 %>% filter(subslab_conc2 > 100*bkgd) %>% mutate(step = step.name)
    } else if(subset.name == "Soilgas") {
      step.name = "SG > 500X Bkgd"
      data2d <- data1 %>% filter(soilgas_conc2 > 500*bkgd) %>% mutate(step = step.name)
    } else if(subset.name == "Groundwater") {
      step.name = "GW > 1000X Bkgd"
      data2d <- data1 %>% filter(gdw_conc2 > 1000*bkgd) %>% mutate(step = step.name)
    }
  sum.step2d <- screensum.fun(data2d)

  ###Step 2e: source strenth screening: SS > 500X bkgd, GW > 5000X bkgd
  if(subset.name == "Subslab") {
    step.name = "SS > 500X Bkgd"
    data2e <- data1 %>% filter(subslab_conc2 > 500*bkgd) %>% mutate(step = step.name)
    } else if(subset.name == "Groundwater") {
      step.name = "GW > 5000X Bkgd"
      data2e <- data1 %>% filter(gdw_conc2 > 5000*bkgd) %>% mutate(step = step.name)
    } else data2e <- NULL
  if(is.null(data2e)) sum.step2e <- NULL else sum.step2e <- screensum.fun(data2e)

  ###Step 2f: source strenth screening: SS > 100X bkgd, SG > 500X bkgd, GW > 1000X bkgd
  if(subset.name == "Subslab") {
    step.name = "SS > 1000X Bkgd"
    data2f <- data1 %>% filter(subslab_conc2 > 1000*bkgd) %>% mutate(step = step.name)
    } else data2f <- NULL
  if(is.null(data2f)) sum.step2f <- NULL else sum.step2f <- screensum.fun(data2f)

  output.sum <- rbind(sum.step0, sum.step1, sum.step2a, sum.step2b, sum.step2c, sum.step2d, sum.step2e, sum.step2
f) %>%
    mutate(subset = subset.name,
           step = factor(step, level = c("Aggregate",
                                         "AF < 1",
                                         "IA > Bkgd",
                                         "SS > 10X Bkgd","SG > 50X Bkgd", "GW > 100X Bkgd",
                                         "SS > 50X Bkgd","SG > 100X Bkgd", "GW > 500X Bkgd",
                                         "SS > 100X Bkgd","SG > 500X Bkgd", "GW > 1000X Bkgd",
                                         "SS > 500X Bkgd", "GW > 5000X Bkgd",
                                         "SS > 1000X Bkgd"
                                         )))

  output <- list(sum = output.sum, data0, data1, data2a, data2b, data2c, data2d, data2e, data2f)
  return(output)
}
```

Appendix 3

Description of Database Input Fields

Each input field in the vapor intrusion empirical database is described below. This information was collected for every paired measurement. Also, the title of the input field as denoted in the database in provided in parentheses.

General Site Information

- Site Name: Name denoted in EnviroStor. (site_name)
- EnviroStor Identification Number: Project number denoted in EnviroStor. (site_id)
- DTSC Project Manager: Regulatory case worker assigned to the project. (dtsc_pm)
- Project Site Address: Address denoted in EnviroStor. (site_add)
- City: City denoted in EnviroStor. (site_city)
- Name of Database Entry Staff: Name of the DTSC employee responsible for data input. (dtsc_de)
- Site Type: The type of corrective action project was denoted; dry cleaner, military site, RCRA corrective action, State response or NPL, or voluntary cleanup project. (site_type)
- Status of Project in EnviroStor: The status of corrective action project was denoted; active, certified, certified – O&M, inactive – action required, or inactive – needs evaluation. (site_status)

Site Specific Information

- Building Chemical Inventory: Was a chemical inventory for possible indoor air sources performed; yes, no, or unknown. (indoor_inventory)
- Building Indoor Air Source: Was an indoor air sources present during sampling: yes, no, or unknown. (indoor_airsource)
- Name of the Chemical Analyzed: PCE, TCE, and associated daughter products. (chem_name)
- Subsurface Preferential Pathways: Were preferential pathways observed such as soil cracks or sand channels in the subsurface; yes, no, or unknown. (bldg_pathway)
- Building Preferential Pathways: Were preferential pathways observed such as utility corridors or sumps; yes, no, or unknown. (bldg_atyroute)
- Summa Canister Pressure: Was there a change in canister pressure between the field and laboratory; yes, no, or unknown. (indoor_canpre)

- Soil Gas Leak Checking: Was a leak check compound used during sample collection; yes, no, or unknown. (soilgas_leak1)

- Soil Gas Leak Check Results: Was the leak check compound detected at unacceptable concentrations; yes, no, or unknown. (soilgas_leak2)

- Predominant Soil Type: What the soil type under the building; coarse, silt, clay, or mixed. (site_soiltype)

Building Information

- Building Name: Name as denoted in the assessment reports. (bldg_name)

- Building Height: Taken for the assessment reports or estimated using professional judgment. (bldg_height)

- Building Use: Residential, commercial, or industrial. (bldg_use)

- Building Type: Apartment complex, single family home, church, office complex, school, shopping plaza, or warehouse. (bldg_type)

- Space Type: Basement, bathroom, bedroom / living space, classroom, kitchen, large space, storage, or office. (bldg_spacetype)

- Building Size: Taken for the assessment reports or estimated from site maps or from Google aerial photographs. (bldg_footprint)

- HVAC System Operation: Was the HVAC operating during indoor air sampling; yes, no, not present, or unknown. (bldg_hvac)

- Foundation Type: Basement, crawl space, slab-on-grade, or unknown. (bldg_foundtype)

Subslab Sampling Information

- Subslab Sample Identification Number: Name as denoted in the assessment reports. (subslab_id)

- Subslab Sampling Date: Date as denoted in the assessment reports. (subslab_date)

- Distance Between Subslab Location and Indoor Air Location: Distance measured from site maps. (distance_subslab_indoor)

- Subslab Sample Result: Result as denoted in the assessment reports and/or laboratory reports (numerical value or ND). (subslab_conc)

- Were Data Flagged by the Laboratory: J, U, H, or UJ. (subslab_flag)

- Sample Reporting Limit If the Subslab Result Was Non-Detectable: Laboratory reports were reviewed. (subslab_rl)

- Sample Method Detection Limit If the Subslab Result Was Non-Detectable: Laboratory reports were reviewed. (subslab_mdl)

Soil Gas Sampling Information

- Soil Gas Sample Identification Number: Name as denoted in the assessment reports. (soilgas_id)
- Soil Gas Sampling Date: Date as denoted in the assessment reports. (soilgas_date)
- Is the Soil Gas Sample Inside or Outsite the Building: Information taken from site maps. (soilgas_loc1)
- Landscape Type of the Exterior Soil Gas Sample: Sample collected from under pavement or non-pavement areas, or unknown. (soilgas_id)
- Distance Between Exterior Soil Gas Location and Building Wall: Distance measured from site maps. (distance_soilgas_bldg)
- Distance Between Soil Gas Location and Indoor Air Location: Distance measured from site maps. (distance_soilgas_indoor)
- Depth of Soil Gas Sample: Information taken from assessment reports. (soilgas_depth)
- Soil Gas Sample Result: Result as denoted in the assessment reports and/or laboratory reports (numerical value or ND). (soilgas_conc)
- Were Data Flagged by the Laboratory: J, U, H, or UJ. (soilgas_flag)
- Sample Reporting Limit If the Soil Gas Result Was Non-Detectable: Laboratory reports were reviewed. (soilgas_rl)
- Sample Method Detection Limit If the Soil Gas Result Was Non-Detectable: Laboratory reports were reviewed. (soilgas_mdl)

Groundwater Sampling Information

- Is the Groundwater Depth Less Than Five Feet: Yes, no, or unknown. (bldg_gdwdepth5)
- Groundwater Sample Identification Number: Name as denoted in the assessment reports. (gdw_id)
- Groundwater Sampling Date: Date as denoted in the assessment reports. (gdw_date)
- Type of Groundwater Sample: Monitoring well or grab sample. (gdw_type)
- Is the Groundwater Sample Inside or Outside the Building: Information taken from site maps. (gdw_loc1)

- Distance Between Groundwater Location and Building Wall: Distance measured from site maps. (distance_gdw_bldg)

- Distance Between Groundwater Location and Indoor Air Location: Distance measured from site maps. (distance_gdw_indoor)

- Depth of Groundwater Sample: Information taken from assessment reports. (gdw_depth)

- Groundwater Sample Result: Result as denoted in the assessment reports and/or laboratory reports (numerical value or ND). (gdw_conc)

- Were Data Flagged by the Laboratory: J, U, H, or UJ. (gdw_flag)

- Sample Reporting Limit If the Groundwater Result Was Non-Detectable: Laboratory reports were reviewed. (gdw_rl)

- Sample Method Detection Limit If the Groundwater Result Was Non-Detectable: Laboratory reports were reviewed. (gdw_mdl)

- Henry's law constant: Values taken from USEPA (2015). (gdw_h_constant)

Indoor Air Sampling Information

- Indoor Air Sample Identification Number: Name as denoted in the assessment reports. (indoor_id)

- Indoor Air Sampling Date: Date as denoted in the assessment reports. (indoor_date)

- Type of Indoor Air Sample: Summa canister or passive sampler. (indoor_samptype)

- Indoor Air Sample Result: Result as denoted in the assessment reports and/or laboratory reports (numerical value or ND). (indoor_conc)

- Duration of Indoor Air Sample: Information taken from assessment reports. (indoor_sampdur)

- Were Data Flagged by the Laboratory: J, U, H, or UJ. (indoor_flag)

- Sample Reporting Limit If the Indoor Air Result Was Non-Detectable: Laboratory reports were reviewed. (indoor_rl)

- Sample Method Detection Limit If the Indoor Air Result Was Non-Detectable: Laboratory reports were reviewed. (indoor_mrl)

Outdoor Air Sampling Information

- Outdoor Air Sample Identification Number: Name as denoted in the assessment reports. (outdoor_id)

- Outdoor Air Sampling Date: Date as denoted in the assessment reports. (outdoor_date)

- Type of Outdoor Air Sample: Summa canister or passive sampler. (outdoor_samptype)
- Outdoor Air Sample Result: Result as denoted in the assessment reports and/or laboratory reports (numerical value or ND). (outdoor_conc)
- Duration of Outdoor Air Sample: Information taken from assessment reports. (outdoor_sampdur)
- Were Data Flagged by the Laboratory: J, U, H, or UJ. (outdoor_flag)
- Sample Reporting Limit If the Outdoor Air Result Was Non-Detectable: Laboratory reports were reviewed. (outdoor_rl)
- Sample Method Detection Limit If the Outdoor Air Result Was Non-Detectable: Laboratory reports were reviewed. (outdoor_mrl)

Appendix 4
Summary Sheets for Individual Sites in Database

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	4906 Alcoa
Site Address	4906 Alcoa Avenue Vernon, California 90031
Oversight Agency	DTSC
Type of Site	CERCLA
Site Documents https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/2357836663/20180406_Alcoa_%20Indoor%20Air%20Sampling%20Results%20%28revised%29_EnSafe.pdf (Pg. 8, 15-31) Indoor Air https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/3408940196/20171215_Alcoa%20Vernon%20Addendum%20to%20PEA-Equivalent%20Final_EnSafe.pdf (Pg. 29, 50-51) Soil Vapor	
Description of Buildings Subject to Testing One warehouse of approx. 42,000 sq ft. Commercial property with commercial workers, passive ventilation system operating 100% of the time, building of unknown age. Slab on grade construction, commercial concrete slab >4ft thick in areas.	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Ace Clearwater Enterprises
Site Address	14105 SOUTH GARFIELD AVENUE AND 7322 QUIMBY, PARMOUNT, CA
Oversight Agency	DTSC
Type of Site	Consent Order
Site Documents Groundwater data and 2015 sub-slab and indoor air: https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/2249621331/Facility%20Investigation%20Report-%20ACE%20Clearwater.pdf 2013 IA Report https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/3599470376/ACE%20Clearwater%20Indoor%20Air%20and%20CPT%20Assessment.pdf	
Description of Buildings Subject to Testing This is a multi-parcel industrial facility beginning approximately in 1959 containing as many as four large buildings used for manufacturing metal parts and storage of manufactured parts and dyes for the aerospace industry primarily. The precise sizes for the four structures on-Site are unclear and the scales on the figures may not be accurate. Building sizes and heights for two of the three buildings (Buildings 1 and 2) are described in June 2013 soil gas assessment report but are not completely verified. They appear somewhat larger than described. The figures also do not provide all partitions or distinguish building spaces from overhangs which are present. Building 2 is used for parts finishing (grinding) as well as small office and employee break areas, bathrooms and changing areas. Building 1 contains offices, storage and logistical operations and attached is a large storage area which is more of an overhang than a building. The Hammer shop contains a lead foundry for making dyes for the parts and massive drop hammers for shaping parks. The hammer shop and building 1 to a lesser extent are open and naturally ventilated. A portion of building 2 in the grinding areas may be under some negative pressure from operational ventilation. Building 2 also has large role up doors. A fourth structure subdivided into areas called a trim shop and storage building was not sampled. There is clearly one error in the figure. The position of monitoring well MW-7 changes with reports. The position from older reports (2011) was used. All distances between locations are estimated from the figures but are likely of limited accuracy. Vapor extraction and air sparging of groundwater was previously performed. SVE was shut down in November 2011. There is clearly residual vadose zone and groundwater sources still present. A main source area was just south of building 1 in an area known as the clean line.	
Description of Indoor Air Testing Indoor air was performed in 2013 and again 2015. Sub-slab samples were taken together with the 2015 samples. There is also soil-gas data taken in 2013 however	

this was greater than three months earlier and is therefore unusable. The indoor air sample names and some of the locations are not the same with sampling events.

There are multiple groundwater samples to pair with the indoor air including permanent monitoring wells which are more at the edges of the plume and CPT samples that were taken in 2015 in more central areas.

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Aerojet General Corporation
Site Address	Hwy 50 and Aerojet Road, Rancho Cordova
Oversight Agency	DTSC
Type of Site	State Response/NPL
Site Documents DRAFT VAPOR INTRUSION FIELD, INVESTIGATION REPORT (WINTER 2016/2017-FALL 2017), dated March 2018. https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/4357787191/VI%20Report_Aerojet_DRAFT.pdf	
Description of Buildings Subject to Testing Indoor air was evaluated in a total of 62 buildings onsite in the Winter of 2017. Sub-slab vapor samples were collected in just three of those buildings. Building 20-001 is used by Aerojet for office space/administration. The building is located near a known soil vapor source. Building 20-004 is used by Aerojet for manufacturing. Area 22, known as Mezzanine M, is a small office and conference room located in the southwest corner of Building 20-004; sub-slab and indoor air samples from this area are included in the spreadsheet. There is a 10-foot deep sump pit in the adjacent area. Building 38-001 is used by Aerojet as a control room for the adjacent test facility. TCE was detected at concentrations above the action level in indoor air samples collected from the J1 control room, the J2 control room, the J3 control room, and the conference room in winter2016/2017; some of these results also exceeded the URAL. Exceedances were exhibited in both HVAC-on and HVAC-off samples. The maximum TCE concentration detected in Building 38-001 was 730 µg/m3 (HVAC-off). TCE was not detected above the chronic SL for commercial air in IA samples collected from the restricted room or the TIC shop. Large utility conduits were present in the floor of this building, HAPSITE evaluation inside conduits identified this as the pathway/source for TCE. Subsequent mitigation reduced concentrations.	
Description of Indoor Air Testing Indoor air samples were collected in January - March of 2017 in a total of 62 buildings. Subsequent sub-slab samples were obtained from only three of those buildings (20-001, 20-004, and 38-001) Pair Information: Building 20-001: Number of Indoor Air to Sub-slab Pairs: 5 total (subslab samples collected 4/24/2017) Building 20-004: Number of Indoor Air to Sub-slab Pairs: 4 total; 2 sub-slab locations (collected 1/19/2017) paired with indoor air collected with both HVAC on and HVAC off Building 38-001 Number of Indoor Air to Sub-slab Pairs: 6 total (4 sub-slab locations, two with both HVAC on and HVAC off indoor air data associated with them) Groundwater data was not readily available via EnviroStor but likely does exist and could be paired with this site, if the hours become available to make these pairings.	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	ALUMIN-ART PLATING COMPANY
Site Address	803 West State St, Ontario , CA 91762
Oversight Agency	DTSC
Type of Site	VCA/State Response
Site Documents	
Description of Buildings Subject to Testing Located in a mixed industrial and residential area and has operated a plating shop at the site since 1965. PCE was used at the site until 1980s. Onsite industrial building: ~40 yrs old, single story + loft, 4,000 sq ft. Offsite residence south of the site (428 Cypress Ave): 41-47 yrs old, single story, 1,000 sq ft.	
Description of Indoor Air Testing Onsite: 3 IA + 1 OA samples on 7/31/14; SG sampling conducted in August 2012 No pairing due to violation of the time criterion (> 3 months) Offsite: 2 IA + 1 OA sample; 1 subslab sample on 7/31-8/1/14 Number of Indoor Air to subslab Pairs: 2	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Carmel Cleaners
Site Address	SWC of Junipero Street & 3rd Ave
Oversight Agency	DTSC
Type of Site	Dry Cleaner under Clean-up Order
Site Documents Sub-slab, Indoor Air and Outdoor Air sampling for 8/24/16 https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/7674944818/20170217_remed_inv_rpt_and_wp_final.pdf	
Description of Buildings Subject to Testing Three separate slab on grade businesses. There is an underground parking structure adjacent to 2 of the buildings. The Pilates Studio is a two-story structure and the second story is a hotel.	
Description of Indoor Air Testing: Occurred 8/24/16. PCE detected at concentrations of 7.7 ug/m3, TCE at 0.22 ug/m3 and cis-1,2 DCE = 0.08 ug/m3 Pair Information: Number of Indoor Air to Sub Slab Pairs: 3 (nearest groundwater paired with indoor air) 3 Outdoor Air Samples	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	CLA-VAL Facility
Site Address	1701 Placentia Avenue Costa Mesa, Ca 92627
Oversight Agency	DTSC
Type of Site	Consent Order
Site Documents CAL-VAL4th Rd Indoor Air_Sept2018_Attach.pdf (Received via email directly from Rafat Abbasi, unable to locate on Envirostor) https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/4308033823/Cla-Val%20Chlorinated%20Solvent%20Use%20Letter_with%20Attach%20%28002%29.pdf (Pg. 7, 9-24) Previous Rounds of Indoor Air Sampling and chemical inventory. https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/3759692132/Draft%20RI%20Report_02-04-2019.pdf (Pg. 65-70, 226-406) Site soil data/boring logs	
Description of Buildings Subject to Testing 1 warehouse of approx. 19,200 sq ft. Commercial property with commercial workers + additional offices in building, Active HVAC ventilation system, building of unknown age. Slab on grade construction, utilities punch through slab (electrical, sewer).	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Conoco Phillips Los Angeles Terminal
Site Address	13500 South Broadway, Los Angeles, California
Oversight Agency	DTSC
Type of Site	VCA

Site Documents

Summer 2010 – Off-Site Indoor-Air, Soil-Gas, and Vapor-Intrusion Assessment Sampling, Conoco Phillips Los Angeles East Terminal 0381, 13500 South Broadway, Los Angeles, CA, Prepared by Stantec, dated October 7, 2010.

Data tables begin on page 59 of the pdf

Description of Indoor Air Testing:

Two rounds of soil vapor samples collected, January and February 2010, and again in July 2010.

In total 18 Indoor air, 17 indoor soil vapor samples collected, 8 outdoor air samples collected, and 2 outdoor soil gas samples collected. No information regarding building inventory.

Pair Information:
Number of Indoor Air to Soil Gas Pairs: 60
Number of Indoor Air to Sub-slab Pairs: 56
Number of Indoor Air to Groundwater Pairs: 0

TCE was detected in indoor air and subslab/soil vapor samples collected from Buildings 201, 207, 223, 267, and AAW.

PCE was detected in indoor air and subslab samples collected at Building 207.

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Former Cornell Dubellier Electronics
Site Address	4144 Glencoe Avenue, Marina Del Rey, CA
Oversight Agency	DTSC
Type of Site	Consent Order

Site Documents

Soil gas sample locations are shown in:

Sub-slab data, soil gas and indoor air are shown in two reports from July and August 2005 for the 42xx addresses. Neither is on Envirostor but both are in the files on the R Drive. The files on the R Drive do not appear to be the complete reports as they lack the lab reports. They may be in the files of DTSC staff or in the file room in the Chatsworth office.

The 1999 indoor air data for the 4144 address is also in the 2006 indoor air report on the R drive. Soil gas to pair with the 1999 indoor air in 4144 can be found in Table 3-11 and 3-12 in the draft RAP which I added to the R drive. For some reason, the final RAP on Envirostor is missing all the data tables (3-1 through 3-16). The original reports from Dames and Moore from 1998 and 1999 were not available on EnviroStor for review.

Follow up indoor air sampling in 2006 at 4144 had no paired soil vapor. Remediation also began in the 2006-2007 period.

<u>Description of Buildings Subject to Testing</u>

This site in incorporates not only the single building at 4144 Glencoe Avenue, but also neighboring properties which have been impacted by groundwater and vapor migration. 4144 is a single former manufacturing building with offices and a larger warehouse space which has since been used for a gym, and as a retail show room.

Other properties which have been investigated for vapor intrusion and include soil vapor data that can be paired with indoor air data include the properties referred to as the 42xx properties located generally to the south and roughly down-gradient. Buildings with paired vapor and indoor include 4208 Glencoe, a building made up of 4204 and 4206 Glencoe and the largest building with addresses 4212-4222 Glencoe Avenue. No groundwater samples were taken within 3 months of the 2005-2006 timeframe when indoor air sampled. These buildings are relatively small and subdivided into small spaces with each address. The 42xx properties had sub-slab depressurization systems added after this sampling.

A separate adjacent property to the northeast, 4150 Glencoe was also sampled for indoor air in August 2006, but no soil vapor or groundwater was taken within the prescribed 3-month time frame.

<u>Description of Indoor Air Testing</u>

Within the 42xx buildings two simultaneous indoor air samples were taken per address which was sampled. I could find no figure showing the locations of the samples within each unit. Therefore, I randomly assigned one indoor air sample to one of the two sub-slab soil gas samples which were also in each unit. This should not be a significant issue since the levels in the indoor air samples within each address were very similar. However, the distance between the indoor air and the paired sub-slab or exterior soil gas could only be bounded by the size of the unit since we do not know the specific location. Since the units are small, this does not matter much. One unit (4208) had many exterior soil gas samples. There were too many to pair. I chose one soil gas to pair with one indoor air sample. I attempted to pick samples that bounded the unit spatially and represented the range of concentrations around the building. For samples with duplicates or with multiple depth, I picked the primary sample at 5-ft bgs.

Indoor air in the 4144 property was first sampled in 1999. The data from 1999 and a discussion of the sampling is provided in the 2006 report. The original (Dames and Moore) 1999 report was not available on EnviroStor or in my personal files. It may be in the file room in Chatsworth or with the current PM. Indoor air levels were only a small amount above background. Soil gas is elevated on only one side of the building. Therefore, the low levels measured in the office spaces are from outdoor air and indoor air transfer. All the data is provided.

Additional round of indoor air with more detail available were collected in 2006 and 2007 in 4144. However, there was no additional soil gas collected at that time as all the soil gas samples were completed in 2005. Indoor air levels were much higher at the time, but were collected under different conditions (door and windows closed, HVAC to offices operating.

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	CORONET CLEANERS
Site Address	40645 Fremont Blvd, Unit 22
Oversight Agency	DTSC
Type of Site	Voluntary Cleanup

Site Documents

\\Dtsc-r4file03\vol2\SITE\VI Worksheets\Rafat Abassi\Coronet Cleaners 60001642

Description of Buildings Subject to Testing

The site is dry cleaner shop and is a part of a shopping plaza. The shop is approximately 2,000 square feet and has an approximate height of 12 feet. The shopping center consists of six buildings (Buildings 1 through 6), occupied by various commercial and retail businesses. The area of concern now vacant (a former tenant, Harvest House Church, vacated the premises in December 2013). Commercial development is located to the northwest and northeast of the site, across Grimmer and Fremont, Boulevards, respectively. Multi-family residential property is located to the southeast and southwest of the site.

Description of Indoor Air Testing

In order to further evaluate the potential for vapor intrusion into the site building and to supplement the existing data collected at the site, Terracon conducted an indoor air sampling event, concurrently with the sub-slab sampling activities on August 15, 2013. A total of six (6) indoor air samples, IA-13, IA-14, IA-15, IA-16, IA-20 and IA-21 were collected. The indoor air sampling events were performed in general accordance with the DTSC Guidance for Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air ("Vapor Intrusion Guidance"), dated October 2011.

Each air sample was collected over an 8-hour period (approximately 480 minutes) using a regulatory flow-control device affixed to a 6-Liter capacity Summa™ stainless steel canister. For the indoor air samples, the canisters were placed in the approximate center such that the sample inlets were located between 3 and 5 feet above the floor in the approximate location of the breathing zone.

Based on the commercial use of the property, the indoor air samples were collected during the course of normal business hours under conditions that were considered relatively typical of daily operations at the site. During each sampling event, windows/doors were closed and the building HVAC system was allowed to operate for brief periods of time, when necessary, to maintain a consistent temperature of approximately 65-72 F, typical of normal conditions for a given weekday when the building is in use. Therefore, a reasonable amount of outside air exchange was allowed to occur within the building during the course of each sampling period, as is consistent with the indoor air sampling protocol outlined in the DTSC Advisory for Active Soil Gas Investigations, dated April 2012.

Pair Information
Number of Indoor Air to Soil Gas Pairs: 4
Number of Indoor Air to Sub-slab Pairs: 4
Number of Indoor Air to Groundwater Pairs: 2

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Crieghton's Cleaners
Site Address	5951 Spring Street Long Beach, CA 90808
Oversight Agency	DTSC
Type of Site	Commercial (Warehouse Structure Grocery Store)
Site Documents https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/5156466424/Additional%20Site%20Assessment%20Report_11-10-16.pdf Main document - Text and Background info (Figure used for pair generation on pg. 26) (Tables start on pg. 44)	
Description of Buildings Subject to Testing 1 Major building (Grocery Store Warehouse Style Building) divided into 6 smaller businesses (3 sampled in sampling event; Pavilions Grocery, Creighton's Cleaners, and Vacant Suite) Building Slab on grade with utilities through slab a each of the subdivided structures. *All samples tested for PCE, TCE, 1,1-DCE, and VC	
Description of Indoor Air Testing 8 Pairs, Indoor air, Sub slab & soil gas, and Groundwater All samples tested for PCE & TCE *Method detection limits for groundwater samples were not given in data package.	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	E Street Plaza
Site Address	640-692 E Street, Chula Vista, California
Oversight Agency	DTSC
Type of Site	Commercial/Residential

Site Documents

https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/7020985245/4Q11%20SVE%20Status%20Report.20120217.f.pdf

Description of Buildings Subject to Testing

The site encompasses approximately 3.4 acres at addresses 640 to 692 E Street in Chula Vista. The testing was performed in shopping plaza units and apartment building located adjacent to the shopping center.

Description of Indoor Air Testing

Indoor air samples were collected in individually certified 6-liter Summa canisters equipped with 8-hour flow controllers provided by the laboratory. Samples were analyzed in accordance with modified EPA Method TO-15M single-ion monitoring (SIM) for PCE, trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), and vinyl chloride.

Pair Information
Number of Indoor Air to Soil Gas Pairs: 56 (combination pairs at two depth); 16 pairs are from residential apartment buildings. The approach for pairing was to apply both nearest neighbor and combination pairing. More than one indoor air samples were paired with soil gas samples at multiple depths.
Number of Indoor Air to Sub-slab Pairs: 5
Number of Indoor Air to Groundwater Pairs: 0

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	EMBEE PLATING
Site Address	2144 South Hathaway
Oversight Agency	DTSC
Type of Site	RCRA Corrective Action
Site Documents https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/4240934610/voc%20invest%20rpt_082313_fnl_COMPLETE.pdf https://www.envirostor.dtsc.ca.gov/screens/menu.asp?global_id=30340013&table_name=COMPLIANCE_MANAGER&mycmd=viewdoc&doc_id=60471005 https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/7789184391/2013%20IOA%20and%20SS%20Sampling%20Report_022114_fnl_COMPLETE.pdf	
Description of Buildings Subject to Testing: The facility consists of approximately 5.2 acres of land and includes buildings 2148 and 2139 and other structures related to its manufacturing operations. It has historically been used for metals plating including use of chromium, tin, nickel, and copper. Tetrachloroethene (PCE) and 1,1,1-trichloroethane (1,1,1-TCA) were used as vapor degreasing agents in the plating operation. 2148 Building: 1080 square foot 2139 Building: 16,000 square foot	
Description of Indoor Air Testing Each indoor air sample was collected in a 6-Liter individually-certified Summa™ canister equipped with a built-in vacuum gauge and a laboratory-certified flow controller set to collect a time integrated sample over approximately eight hours. Individual certification means that each canister processed (i.e., cleaned using a combination of dilution, heat, and high vacuum) is sampled and analyzed for the project-specific target analyte list by Gas Chromatography/Mass Spectrometry (GC/MS), and that concentrations of target compounds are below project reporting limits. Individual certification is also made using matching components (i.e., a particular flow controller is matched with a particular canister). Sample 1 was collected in an occupied office area located at the northeast corner of Building 2158. Sample 3 was collected within Building 2148 approximately 20 feet to the west of the main entrance. An indoor air sample was previously collected from this location in October 2012 and April 2013. Sample 4 was collected in a previously	

sampled location (2012) beneath an open staircase just outside of the Mask Room in Building 2148. Sample 5 was collected in Building 2139 in the approximate center of the building near the former degreasing tank (AOC 8). Sample 6 was collected within Building 2139 along the south wall at the approximate midpoint between sub-slab soil gas probes VP-5 and VP-6; and Sample 8 was collected in Building 2139 near the chromium treatment system and just south of sub-slab soil gas probe VP-7.

After talking to the project toxicologist, it was determined that sub-slab probes had significant leaks and may have served as a preferential pathway for indoor air contamination. The project proponent abandoned and sealed the probes. Additionally, the floors in the buildings were sealed to ensure that there are no other preferential pathways. The data quality staff determined that the data associated with this site should not be used for calculation of attenuation factors.

Pair Information

Number of Indoor Air to Soil Gas Pairs: 0
Number of Indoor Air to Sub-slab Pairs: 7
Number of Indoor Air to Groundwater Pairs: 0

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Flamingo Cleaners
Site Address	26512 Bouquet Canyon Road, Santa Clarita, CA 91350
Oversight Agency	DTSC
Type of Site	VCA, dry cleaner
Site Documents Site Investigation – Former Flamingo Cleaners, 26512 Bouquet Canyon Road, Santa Clarita, CA https://www.envirostor.dtsc.ca.gov/screens/menu.asp?global_id=60001168&table_name=COMPLIANCE_MANAGER&mycmd=viewuploaded&doc_id=6028240	
Description of Buildings Subject to Testing The former dry cleaner is located in a commercial shopping center. A first set of indoor air samples were collected from the bathroom and in the front and rear portions of the narrow tenant space (and one outside air sample). A second indoor air sampling event collected only 1 sample in the middle of the dry cleaner space, no outdoor air sample was collected.	
Description of Indoor Air Testing Indoor air sampling collected on 3/1/2011 and 3/29/2011 – Unable to locate any building inventory/pre-indoor air chemical survey or any field screening. Soil vapor sampling collected on 4/12/2011 Groundwater sampling collected on 3/1/2011 Pair Information: Number of Indoor Air to Soil Gas Pairs: 2 Number of Indoor Air to Sub-slab Pairs: 2 Number of Indoor Air to Groundwater Pairs: 1	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	General Atomics
Site Address	Southwest of I-5 and I-805 interchange in Sorrento Valley, San Diego
Oversight Agency	DTSC
Type of Site	Corrective Action Fee for Service Agreement

Site Documents

Long-Term Indoor Air Monitoring 2015, General Atomics Building 37, April 11 2016
https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/2145388543/GA_LTIA%20Monitoring%20Report_2016.04.11.final.pdf

Building 37 Interior Subsurface Investigation Report, May 11, 2017
https://www.envirostor.dtsc.ca.gov/screens/menu.asp?global_id=80001461&table_name=COMPLIANCE_MANAGER&mycmd=viewuploaded&doc_id=60417626

Only the 2 reports listed above (that were provided to the reviewer by the team leaders) were reviewed. A scan of EnviroStor shows that this is an active site with a long history and potentially a number of other VI-related data sources may be available on EnviroStor. The project team should be consulted.

Description of Buildings Subject to Testing

Building 37 is an active research and development facility. The building has undergone various expansions and modifications during its approximately 40 years of use. It occupies approximately 38,000 square feet. It is a multi-story structure with a monolithic floor slab.

Description of Indoor Air Testing

Indoor air sampling – 12/4/2015
Sub-slab sampling – 1/18/2016
Soil-gas sampling – 2/16 & 17/2016

A number of other pairs could have generated but only the nearest pairs were selected.

Pair Information:
Number of Indoor Air to Soil Gas Pairs: 18 (nearest soil gas paired with indoor air)
Number of Indoor Air to Sub-slab Pairs: 6 (co-located)
Number of Indoor Air to Groundwater Pairs: 0 (nearest groundwater paired with indoor air)

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Green's Cleaners
Site Address	4600 Firestone Boulevard
Oversight Agency	DTSC
Type of Site	Dry Cleaner: State response or NPL

Site Documents

Remedial Investigation Addendum Report, Green's Cleaners, South Gate, California, prepared by Genesis Engineering and Redevelopment, dated August 13, 2019.

Data tables start at Page 55 of the PDF.

Description of Buildings Subject to Testing

Three building in total as part of the study, 4600 Firestone Blvd, "Green's Cleaners" a dry cleaner that has been in business since 1940s when the building was constructed. Adjacent buildings located at 4606 Firestone Boulevard and 8912 Kaufman Avenue were included in the study, no information regarding these buildings were encountered in the report.

Description of Indoor Air Testing

There were multiple rounds of indoor air testing, dates included for the study include:

5/9/2018
1/10/2018
11/9/2017
9/21/2016 or 10/25/2016

A Soil Vapor Extraction pilot test began on 6/29/2018. No data was entered into the spreadsheet from sampling events after this date.

Pair Information:
Number of Indoor Air to Soil Gas Pairs: approximately 17 pairs with approximately 4 rounds of indoor air pairing (nearest soil gas paired with indoor air)
Number of Indoor Air to Sub-slab Pairs: 5 (co-located)
Number of Indoor Air to Groundwater Pairs: 0 (nearest groundwater paired with indoor air)

Indoor air samples detected concentrations of PCE and TCE with soil vapor and sub slab data detecting PCE, TCE, and to a lesser extent cis-1,2-DCE, trans 1,2-DCE and vinyl chloride.

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Hughes Torrance EDD Facility
Site Address	3100 Lomita Boulevard, Torrance
Oversight Agency	DTSC
Type of Site	Commercial

Site Documents

https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/9733136832/2007-12-17%20Revised%20HHRA%20%28GeoSyntec%29.pdf

Description of Buildings Subject to Testing

Indoor air samples were collected at 25 locations in Buildings 230, 231, and 232 at the Site. The locations were based on the results of the sub-slab soil gas investigation, location of preferential migration pathways, and chemical use in the buildings. Buildings 233 and 234 contain equipment and are generally not occupied by employees.

Consideration of outdoor and indoor sources of chemicals was a key component of the indoor air sampling plan. Outdoor air samples were collected to evaluate background concentrations that may affect the indoor air sample results. Chemical use at this Site is common and hundreds of chemicals have been reported to be stored and/or used in the buildings to be tested. Consequently, chemical use was evaluated through review of Site chemical inventories and discussion with Site representatives.

Description of Indoor Air Testing

The chemical use was evaluated through review of Site chemical inventories and discussion with Site representatives. Indoor Air Sample Locations: Indoor air samples were collected at several locations in Buildings 230, 231, and 232 at the Site. The locations were based on the results of the sub-slab soil gas investigation, location of preferential migration pathways, and chemical use in the buildings. At each location, samples were collected over an approximately 24-hour period. Additionally, a subset of these locations was selected for samples to be collected over an 8-hour period to evaluate indoor air concentrations during the work day. The VOCs were analyzed by TO-15 SIM. Since daughter products were always not detected, it was decided not to include the data in the data entry work sheets.

Pair Information
Number of Indoor Air to Soil Gas Pairs: 54
Number of Indoor Air to Sub-slab Pairs: 7
Number of Indoor Air to Groundwater Pairs: 0

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Kast Site
Site Address	Multiple sites in residential development in Carson, Ca (Former Kast Property)
Oversight Agency	
Type of Site	Residential (Suburban residential development of single-family homes)
Site Documents: Revised Site-Specific Cleanup Goal Report Former Kast Property Carson, California (DTSC not lead oversight agency, document not on EnviroStor)	
Description of Buildings Subject to Testing: Multiple single-story, single family homes in suburban residential development in Carson, Ca. Buildings Slab on grade with utilities through slab at each of the buildings. *All samples tested for multiple VOCs, only PCE was examined for vapor intrusion pairs. *Some buildings had multiple rounds of sampling when VOCs were found in Indoor air or soil gas.	
Description of Indoor Air Testing: Indoor air quality survey and additional subsurface investigation. Pairs are sub-slab soil gas + indoor air + outdoor, multiple paired samples per building. 198 pairs of sub-slab soil gas + indoor air + outdoor air, Samples taken between 2011-2013. Outdoor air samples were taken in vicinity of building in question and are actual paired data. *Method detection limits for soil gas samples were not given in data package, just reporting limit for non-detects, without lab data package, accurate method detection limits and reporting limits could not be found.	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Modesto Groundwater Investigation
Site Address	1425 La Loma Avenue and 1645 Princeton Avenue, Modesto, CA
Oversight Agency	DTSC
Type of Site	Dry Cleaner

Site Documents

Former Service Cleaners (1425 La Loma Avenue)
https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/4469116032/IA_results.pdf
Figure 3 for indoor Air sample locations:
https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/2277775406/Figures_reduce.pdf

Former Sunshine Cleaners (1645 Princeton Avenue)
https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/7475996255/Sunshine%20VMP_IA%20and%203rd%20Quarter%202014%20report_110314.pdf
Figures 4-6 for sample locations:
https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/7054670572/SVE%20Long-Term%20Pilot%20Test%20SAP_07-02-15%20%282%29.pdf

Description of Buildings Subject to Testing

Former Service Cleaner:
Approximately 1425 square foot single story building previously used as a dry cleaner. No hazardous waste ledgers were ever produced for this site indicating that PCE that was used was dumped directly into the stained and damp area behind the building. Samples were obtained from the main office area located on the East side of the building and the bathroom located in the Northwestern corner. Indoor air samples were

Former Sunshine Cleaners:
Approximately 4200 square foot building used as a carpet and drapery cleaners. Two samples were collected in the indoor air. One in the front indoor air space and one in the back bathroom.

Description of Indoor Air Testing

Former Service Cleaners:
Samples were obtained (8-hour samples) from the main office area located on the East side of the building and the bathroom located in the Northwestern corner. Indoor air results were nearly identical for the two locations (PCE at 640 and 630 μg/m^3). While several soil vapor and groundwater monitoring wells exist in the vicinity of the building only one soil vapor monitoring well (IA3-VMP-3) meets the inclusion requirements for pairing. Soil vapor from this well was collected at three depths: 5, 15, and 45 ft bgs. Given that IA3-VMP-3 is near to the office and the indoor air sample results were so similar, only the one indoor air sample (office PCE 640 μg/m^3) was entered into the database.

Former Sunshine Cleaners:
Indoor air samples were collected (8 hours) from the from the South end of the building in an office area and from the Northwestern corner in the bathroom. One subslab sample (IA13-VMP-1A) and one groundwater sample (IA13-MW-1A) met the criteria for pairing. Both were nearest the office indoor air data sample. So total of 2 pairs for this site.

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	MOUNTAIN SQUARE CLEANERS
Site Address	384 and 386 South Mountain Avenue, Upland , CA 91786
Oversight Agency	DTSC
Type of Site	VCA
Site Documents	
Description of Buildings Subject to Testing Located in a retail shopping center within a mixed-use area. A former dry cleaners operated at 386 South Mountain Avenue from 1989 to 1995. Currently Mountain Square Cleaners has operated at 384 South Mountain from 1995 until present. Onsite Shopping Plaza: 29 yrs old, single story w/ multiple suites (varying in size).	
Description of Indoor Air Testing Interior: 5 IA (including a duplicate pair) + 1 OA samples in April 2018; 3 subslab (including a duplicate pair) in Ste 384 4 nested SG probes in Ste 380, 382 and 386 (SVP-8-10, 13); 2 exterior locations (SVP-11,12) Number of Indoor Air to subslab/SG Pairs: 9/16 Ste 380: 1/4 (AM-1 and SS-1; SVP-13-6/10/DUP-3/15') Ste 382: 1/1 (AM-2 and SS-1; SVP-9-6') Ste 384: 6/2 (AM-3/AM-3D and SS-1/SS-2/SS-Dup; SVP-9-6') Ste 386: 1/9 (AM-4 and SS-1; SVP-8-5/10/14', SVP-10-6/10/15' and SVP-12-5/10/Dup-4) SVP-11 not used (the closest IA location AM-4 has 9 paired data already)	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Naval Air Station North Island
Site Address	Coronado, CA
Oversight Agency	DTSC
Type of Site	Military

NOTE: INCOMPLETE EVALUATION – ONLY 9 OF 22 BUILDINGS COMPLETED SEE NOTES BELOW

Site Document

Vapor Intrusion Investigations Results Summary Technical Memorandum, IR Site 9, OU 11, and OU 20, September 2019. https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/5962615072/Site%209%20OU%2011%20and%20OU%2020%20VI%20Investigation%20Result%20Tech%20Memo.pdf

Since this is only a summary report, it did not contain pertinent information regarding the building survey, sampling protocols, subsurface information and laboratory reports. Only summary data tables and figures were presented. I could not find on EnviroStor any of the source documents (i.e., reports with laboratory reports and sampling protocols) for all the sampling summarized in this report. The data entered into the spreadsheet is based solely on the data tables presented in the summary report. A workplan was found on EnviroStor, but it is unknown if it was implemented with any deviations until the comprehensive VI report is released.

Excel tables were also found in the R drive, but the source of the Excel tables is unknown and the information presented in the Excel tables could not be verified nor interpreted with great confidence. It is recommended that close coordination with the NASNI DTSC project team be conducted in order to acquire and verify all the applicable data for the site. Based on the other site activities found in EnviroStor, it is very likely that a significant amount of other VI-related data, including groundwater-IA and SG-IA data pairs, are available.

This site has significant amounts of data from a VI study (currently 22 buildings and approximately 220 pairs with multiple sampling events, and additional sampling is planned for more buildings) to specifically calculate building-specific AFs. This site should be given more attention due to the large data-set and the fact that sub-slab-IA co-located samples were designed to specifically calculate AFs.

Note: For Building 379, an SVE was in operation starting 5/18/2016, therefore data during SVE operation was not used in pairing. Significant cracks were found in the building, cracks and joints were sealed between June 2015 to January 2016.

Due to the large data-set and time constraint for the review, only the following buildings were evaluated and pairs were completed and entered into the spreadsheet: 743, 744, 1454, 1472, 1482, 2, 94, 379, 397.

The review of the following buildings was NOT completed: 801, 472, 341, 334, 333, 90, 65, 36, 33, 6, 4, 3, 1.
Description of Buildings Subject to Testing See text above.
Description of Indoor Air Testing See text above. Pair Information: Number of Indoor Air to Soil Gas Pairs: 0 (nearest soil gas paired with indoor air) Number of Indoor Air to Sub-slab Pairs: partially completed (~105 location pairs), (~125 location pairs un-evaluated), see text. Each location pair has up to 6 chemicals (6 data rows). Number of Indoor Air to Groundwater Pairs: 0 (nearest groundwater paired with indoor air)

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	National Steel and Shipbuilding Company (NASSCO) Property
Site Address	Harbor Drive and 28th Street, San Diego, CA 92113
Oversight Agency	DTSC
Type of Site	Tiered Permit

Report: "Results of Sub-Slab Vapor, Indoor Air, and Groundwater Sampling, Building 6 Sump Area of the National Steel and Shipbuilding Company (NASSCO) Property" prepared by CB&I in Irvine, California and dated May 1, 2014. The Report is presented in the format of an 11-page letter with a 1-page certification, Table 1 (Analytical Results for Soil Gas Samples), Table 2 (Indoor and Ambient Air Sample Results), Table 3 (Screening of Sub-Slab Soil Gas Results - 2013 and 2014 Data Building 6), Table 4 (Screening of Sub-Slab Soil Gas Results - 2013 and 2014 Data Building 12), Table 5 (Detected VOCs in Groundwater), Table 6 (Analytical Results for Groundwater Samples), Table 7 (Water Levels and Field Parameters), eight figures and five appendix cover sheets. The appendices were obtained separately. Contaminants of potential concern detected in groundwater monitoring well MW-3 include tetrachloroethene (PCE) and its breakdown products trichloroethene (TCE), *cis*-1,2-dichloroethene and *trans*-1,2-dichloroethene. Of the breakdown products, only TCE was detected in sub-slab soil gas, but not in air samples. All sub-slab vapor samples had significant (1700-3400 μg/m^3) levels of 1,1,1- trichloroethane but this compound was not detected in groundwater or indoor air samples leaving PCE as the only contaminant of concern for the vapor intrusion (VI) investigation.

The NASSCO shipyard facility is located in an industrial use (only) area in the San Diego Port Tidelands where it occupies 80 acres of land and 46 acres of water and where NASSCO has been building and repairing ships since 1960. The Report only mentions two of the buildings, building 6 and building 12, which are separated by a walkway. NASSCO cleaned up and backfilled a small sump east of building 6 after spilled solvents were discovered there in 1989. Originally contamination at both buildings was investigated but the focus of the present VI investigation is building 6 (only). Building 6 is a garage-like structure of approximately 2,900 square feet (estimated age 12 years, building survey) used as a repair shop. A wide variety of chemicals including solvents and paints are being used there (page 3 of the Report). The Report further states on page 3 "*Since the building is an active facility, products were not removed*". Building 6 consists of one large room with large overhead roll-up doors on both ends and two small offices in a corner.

Description of Indoor Air Testing:
Two rounds of indoor air sampling were conducted in 2013 and 2014. Six-liter Summa-type cannisters were used to collect indoor air samples at 5 feet 4 inches from the floor over an 8-hour period (page 3). Five indoor air locations, two subslab locations and three groundwater locations were sampled. Concentrations of chemicals detected were below levels that would have caused human health concerns (page 9). As cited above, numerous solvent-type chemicals including spray paint are being used at the facility and were not removed during the investigation.

	Indoor air	Subslab	Groundwater
2013	6/19/13	6/20/13	6/20/13
2014	1/16/14	1/16/14	1/16/14

Pair Information (nearest groundwater and sub-slab sample paired with each indoor air sample):

2013

Indoor air ($\mu g/m^3$)	Sub-slab ($\mu g/m^3$)	Groundwater ($\mu g/L$)	Notes
6IA-1 (0.16)	SV-1 (10000)	MW-2 (0.52)	
6IA-2 (2.5)	SV-1 (10000)	MW-2 (0.52)	
6IA-3 [ND 0.14]	SV-2 (98000)	MW-1 (1.4)	error msg
6IA-4 (0.67)	SV-2 (98000)	MW-1 (1.4)	
6IA-5 (0.79)	SV-2 (98000)	MW-2 (0.52)	

2014

Indoor air ($\mu g/m^3$)	Sub-slab ($\mu g/m^3$)	Groundwater ($\mu g/L$)	Notes
6IA-1 (0.15)	SV-1 (2700)	MW-2 (1.6)	
6IA-2 (0.2)	SV-1 (2700)	MW-2 (1.6)	
6IA-3 (0.19)	SV-2 (55000)	MW-1 (3.6)	
6IA-4 (0.18)	SV-2 (55000)	MW-1 (3.6)	
6IA-5 (0.23)	SV-2 (55000)	MW-2 (1.6)	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	New LA Charter School
Site Address	1919 South Burnside Avenue, Los Angeles, California
Oversight Agency	DTSC
Type of Site	School repurposed building in industrial area
Site Documents Indoor Air Sampling in December 2017 (Report) Indoor Air and Sub-slab sampling in February 2018 (Report) Indoor Air, Sub-slab and soil vapor sampling July and September 2018 (Report)	
Description of Buildings Subject to Testing The site is a charter school with approximately 300 children. The building is a former manufacturing facility built in 1959. 2.5 Tons of oil/water separation sludge were removed from the site in 2003. The subsurface concentrations of PCE are as high as 10,680 ug/m3 Chloroform and petroleum constituents are also present in high concentrations in the subsurface.	
Description of Indoor Air Testing: Three indoor air sampling events Dec 2017, Feb 2018 and July 2018 Pair Information: Indoor Air from December 2017 paired with sub-slab Feb 2018 (2 pairs) Indoor Air from Feb 2018 paired with sub-slab Feb 2018 (3 pairs) Indoor Air from July 2018 paired with sub-slab from July 2018 (3 pairs) Indoor Air from July 2018 paired with soil vapor data from September 2018 (15 pairs) 3 Outdoor Air Sampling events Dec 2017, Feb 2018 and July 2018	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Former Norge/Atherton Village Cleaners
Site Address	1438 El Camino Real, Menlo Park
Oversight Agency	DTSC
Type of Site	Dry Cleaner
Site Documents Preliminary Site Evaluation Data Submittal https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/8289519369/372657_2019%2011%20Interim%20Data%20Submittal_Menlo%20Park%2C%20CA.pdf	
Description of Buildings Subject to Testing The former Norge/Atherton Village Cleaners is now a restaurant. Soil vapor sampling in 2017 detected both PCE and TCE in the subsurface. The restaurant is approximately 2,400 square feet. Samples were collected in the kitchen area as well as in the dining area.	
Description of Indoor Air Testing Indoor air samples were collected September 30, 2019. Samples were collected over at 9 hour period as that was the reported average shift time for a restaurant worker, co-located Subslab soil vapor samples were collected on 10/01. IA-1 was collected in the dining room; SS-4 was the co-located subslab sample IA-2 was collected in the kitchen area; SS-5 was the co-located subslab sample	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	PACIFIC SCIENTIFIC COMPANY
Site Address	402/411/430 E. GUITERREZ STREET, SANTA BARBARA , CA 93101
Oversight Agency	DTSC
Type of Site	VCA
Site Documents	
Description of Buildings Subject to Testing The property comprises 3.71 acres with four primary buildings and several additional small storage structures: 402 E Gutierrez: occupied by RightScale (an internet software company), 60 yrs/26400 ft2/1 story 411 E Gutierrez: occupied by Kamran & Co (a food service contractor), 60 yrs/11500 ft2/1 story+loft 430 E Gutierrez: occupied by various tenants (a printing studio and several music studios; formerly El Puente Continuation School closed in 2013), 60 yrs/10000 ft2/1 story+loft	
Description of Indoor Air Testing (all work done <u>Nov 2011</u>) 402 E Gutierrez: 5 IA (-7/8/9/10/11); 3 SSL (-402-1/2/3); 3 exterior SGL (-02/09/11) 411 E Gutierrez: 3 IA (-12/13/14); 2 SSL (-411-01/01B); 4 exterior SGL (-04/06/14/14B) 430 E Gutierrez: 5 IA (-1/2/3/4/5); 3 SSL (-430-1/2/3); 6 exterior SGL (-01B/03/05/07/11/12) Four outdoor air samples (OA-1/2/3/4) Total Number of Indoor Air to subslab/SG Pairs: **17/15** 402 E Gutierrez: 5/4 (IA7:1/1, IA8:1/2, IA9:1/0, IA10:1/1, IA11:1/0) 411 E Gutierrez: 6/5 (IA12/IA13[dup]: 4/2, IA14:2/3) 430 E Gutierrez: 6/6 (IA1:1/2, IA2:1/2, IA3:12/0, IA4:1/0, IA5:1/2) Additional rounds of IA/SS/SG sampling were conducted later: • May 2012 (URS, 7/17/13) • November 2014 (URS, 1/30/15) • November 2015 (URS, 2/19/16) • February 2018 (AECOM, 4/4/19) • November 2018 (AECOM, 4/4/19) These results are generally consistent (Sec 5.2/Table 7 in AECOM 4/4/19 Report)	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	PK I COUNTY FAIR SC LP
Site Address	12051 & 12075 Central Avenue, Chino, CA 91710
Oversight Agency	DTSC
Type of Site	VCA, former dry cleaner

Site Documents

Site Characterization Report, Allen Cleaners/Country Fair Shopping Center, March 30, 2018

Description of Buildings Subject to Testing

The Allen Cleaners Site is located within the Country Fair Shopping Center (CFSC), a multi-tenant commercial shopping center. The CFSC is comprised of about 19 acres and was constructed in 1974 with an addition built in 1987. Occupants of the CFSC include various retail stores and restaurants, a pharmacy, hardware store, grocery store, a bank, and Allen Cleaners. Allen Cleaners operated in two different suites at CFSC. Initially, Allen Cleaners was located at 12075 Central Avenue from at least 1987 to 1992. Café Donuts (formerly Golden Donuts) has operated at this location since about 1993. In 1992, Allen Cleaners moved to its current location at 12051 Central Avenue. PCE was reportedly used at both Allen Cleaners locations.

Description of Indoor Air Testing

On September 14, 2017 indoor air sampling was performed to assess potential vapor intrusion at the Allen Cleaners, and adjacent/nearby tenant suites. 15 indoor samples were collected from five suites: the Allen Cleaner facility (12051 Central Avenue), the Café Donuts unit (12075 Central Avenue), the adjoining Payless Beauty Supply (12049 Central Avenue), the adjoining Rite Aid (12059 Central Avenue), and the Taylor's Nail and Spa unit at 12045 Central Avenue. Ambient outdoor air samples were also collected to assess background (i.e. outside) conditions. After the September 16 sampling event, the existing ventilator located on the roof of Allen Cleaners was reversed to discharge outdoor air into the suite. A second round of samples was then collected on November 10, 2017 from inside Allen Cleaners to assess the effectiveness of the introduction of outside air on indoor air quality.

Pair Information:
Number of Indoor Air to Soil Gas Pairs: 70
Number of Indoor Air to Sub-slab Pairs: 65
Number of Indoor Air to Groundwater Pairs: 0

The current operator at Allen Cleaners indicated that chlorinated solvents have not been in use at the current location (12051 Central Avenue) since approximately 2010/2011. Allen Cleaners now conducts wet washing using consumer-grade detergents. It's possible that PCE off gassing from building materials and/or garments is a source of PCE at Allen Cleaners. Note that indoor air samples IAQ2 (Allen Cleaners) and IAQ8 (Rite Aid) are both paired with SV8 sub-slab and soil gas samples. The indoor air concentrations and are two orders of magnitude different at IAQ2 and IAQ8 and the variation may be due to the size of the building and HVAC units; or possibly due to indoor air contaminants at Allen Cleaners.

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Plaza By The Sea
Site Address	610-628 Camino De Los Mares, San Clemente, CA
Oversight Agency	DTSC
Type of Site	VCA

Site Documents

Langan Engineering, 2019. Conceptual Site Model and Vapor Intrusion Investigation Report. May 9.

Relevant sample locations and analytical data are presented in Figure 7.

Description of Buildings Subject to Testing

Co-located sub-slab soil gas and indoor air samples were collected in 5 retail units within three different multi-unit retail structures. The retail units ranged in size from approximately 525 to 2700 square feet. The tenants at the time of sampling included a dry cleaning facility, restaurants, flooring companies, and unoccupied retail space. The buildings were reportedly constructed in the 1970s.

Description of Indoor Air Testing

A total of 10 indoor air samples with six co-located sub-slab soil gas samples were collected during two sampling events (October 2018 and January 2019). Subsurface contaminants of concern detected include PCE and TCE.

Pair Information:
Number of Indoor Air to Soil Gas Pairs: 0 (nearest soil gas paired with indoor air)
Number of Indoor Air to Sub-slab Pairs: 10 (co-located)
Number of Indoor Air to Groundwater Pairs: 0 (nearest groundwater paired with indoor air)

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Shachihata, Inc.
Site Address	1661 W. 240th Street, Harbor City, CA
Oversight Agency	DTSC
Type of Site	VCA

Site Documents

Soil gas and sub-slab soil gas without appendices
https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/8006086051/Shachihata_Final%20Report%20_June%202010.pdf

Indoor Air
https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/2967422306/Indoor%20Air%20Sampling.pdf

<u>Description of Buildings Subject to Testing</u>
This is a single large industrial warehouse type building (100,851 SQFT per the VCA) with an internal area (estimated from figure: 24,000 SQFT offices) which have their own separate HVAC system. The office space was mostly one shared space.

The warehouse portion has very high ceilings and may only be naturally ventilated through the large role up doors or ventilated with fans as is usually the case for such structures. The warehouse space has partitions but with large openings between them in my memory and so I considered the warehouse one large space.

<u>Description of Indoor Air Testing</u>
Indoor air (n=5) was performed in in June 2010 under normal operating conditions (with HVAC). One sample AAI-4 went to zero pressure within 2 hours (actual length unknown).

Sub-slab (n=8) and soil-gas (n=2 with multiple depths were also collected in June 2010. Other soil-gas samples were collected outside the 3-month range. Groundwater is at almost 80-ft bgs,

I paired the 4 indoor air with 5 of the sub-slab soil gas samples and the two 5 and 15 ft soil gas samples. Two sub-slab samples (SS-SG-4 and SS-SG-8) are paired with one indoor air (AAI-2) based upon the nearest neighbor approach for each subsurface sample. One sub-slab sample is also paired with 2 indoor air (AAI-4 and AAI-5) since this is the closet sample to both indoor air samples.

There were three additional sub-slab soil gas samples which were farther away in the warehouse spaces in other partitioned areas which were not paired with any indoor air (SS-SG-1, SS-SG-6, and 7) which I chose not to include.

Since there were only two multi-depth soil gas samples (SG-51 and SG-52) taken close in time, I only paired these samples with their nearest indoor air samples and no other.

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Safety-Kleen – San Jose
Site Address	1147 North Tenth Street, San Jose
Oversight Agency	DTSC
Type of Site	RCRA

Site Documents

Additional RCRA Facility Investigation Indoor/Outdoor Air and Sub-slab Soil Gas Sampling, January 26, 2015
https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/9066207706/IA_OA_SS_sampling_rpt_012615_fnl.pdf

Revised Addendum to the Revised RCRA Facility Investigation Report – December 21, 2015
https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/4564030289/Rev_addendum_to_rev_RFI_120415_report.pdf

Quarterly Progress Report Fourth Quarter 2014, January 2015
https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/3182342350/4Q2014QPRSK-San%20Jose%20Revised%20FINAL.pdf

Description of Buildings Subject to Testing

The facility is located in a commercial/light industrial area. Per the building survey form, the single-story warehouse building with offices is approximately 7,200 square feet and is approximately 40 to 60 years old.

Description of Indoor Air Testing

3 indoor air locations, 1 outdoor air location and 4 sub-slab locations were sampled in July 30 and October 13, 2014. 2 of the indoor air locations were located close to the 4 sub-slab locations, one of the indoor air locations was located at a far wall to the north and was not close to any of the sub-slab locations. The building inventory noted drums in the building with different contents and that the indoor air sampling was performed with a roll-up window open, which is open during normal business hours.

1 groundwater sample from a semi-annual monitoring event (November 25, 2014) was paired with the indoor air sample from October 13, 2014. Additional groundwater wells are present but are only sampled for TPH or are too far from the building.

Pair Information:
Number of Indoor Air to Soil Gas Pairs: 0 (nearest soil gas paired with indoor air)
Number of Indoor Air to Sub-slab Pairs: 6 (co-located)
Number of Indoor Air to Groundwater Pairs: 1 (nearest groundwater paired with indoor air)

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Sunshine Cleaners
Site Address	10750 San Pablo Avenue, El Cerrito
Oversight Agency	DTSC
Type of Site	VCA, dry cleaner

Site Documents

Letter Report for Soil Sub-Slab and Groundwater Sampling at 10750 San Pablo Avenue, El Cerrito, February 27, 2015
https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/7290972650/Soil%20%26%20Groundwater%20Report_10750%20San%20Pablo%20Ave%20February%202015.pdf

Description of Buildings Subject to Testing

The dry cleaner is within a retail strip mall, the areas sampled for indoor air include other tenant areas and is not limited to the dry cleaner, but the majority of the samples are in the vicinity of the dry cleaner (approximately 2,800 square feet).

Description of Indoor Air Testing

The indoor air, sub-slab and groundwater sampling reported in the document were collected prior to DTSC involvement with the project. Groundwater is very shallow and was observed at 4 feet below ground surface.

2 indoor sampling events were performed (12/4/14 & 2/7/15). A combined 5 indoor air samples and 2 outdoor ambient samples were collected during these 2 events. Groundwater and sub-slab sampling were performed on 1/22/15). 1 sub-slab and 3 groundwater samples were collected inside the building. A building inventory was not located in the project files.

Pair Information:
Number of Indoor Air to Soil Gas Pairs: 0 (nearest soil gas paired with indoor air)
Number of Indoor Air to Sub-slab Pairs: 1 (co-located)
Number of Indoor Air to Groundwater Pairs: 4 (nearest groundwater paired with indoor air)

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	6801 SUVA
Site Address	6801 Suva Street. Bell Gardens, California
Oversight Agency	DTSC
Type of Site	

Site Documents

https://www.envirostor.dtsc.ca.gov/screens/menu.asp?global_id=60001333&table_name=COMPLIANCE_MANAGER&mycmd=viewuploaded&doc_id=60253136

https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/3856765568/Suva-Laboratory%20Report%20Indoor%20Air%206-29-15.pdf

Description of Buildings Subject to Testing

The 2.5-acre site consists of two parcels. The 6801 Suva Street Parcel (Suva) and the 6814 Foster Bridge Blvd Parcel (Foster). From 1950 to 2004, Mid Cities Paper Box Company (MCPBC) operated the Site for manufacturing and printing of cardboard boxes, using glues and other solvents which contained tetrachloroethene (PCE) and trichloroethene (TCE).

Description of Indoor Air Testing

The air samples were analyzed by EPA Method TO15 and collected using SUMMA canisters. Each canister was individually certified. The indoor air sampling events were performed in general accordance with the DTSC Guidance for Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air ("Vapor Intrusion Guidance"), dated October 2011. The duration of each sample was 8-hour. The samples were located in an office area and inside the warehouse. Samples IA1, IA3, IA4 and IA5 were used with soil gas samples B9A, B10A and MW3.

Pair Information

Number of Indoor Air to Soil Gas Pairs: 9
Number of Indoor Air to Sub-slab Pairs: 0
Number of Indoor Air to Groundwater Pairs: 0

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Torrance Memorial Specialty Center
Site Address	2841 Lomita Boulevard Torrance, California
Oversight Agency	DTSC
Type of Site	Consent Order
Site Documents https://www.envirostor.dtsc.ca.gov/regulators/deliverable_documents/6786819279/Torrance%20Memorial%20VI%20Report_052617.pdf	
Description of Buildings Subject to Testing This site is a new multi-story (4?) medical offices building which was newly constructed. No information exists on possible on-site sources. The site is also down-gradient or near other sites including those undergoing cleanup. Groundwater is deep and has been relatively low in concentration for some time so that source of the VOCs on-site are unknown.	
Description of Indoor Air Testing Indoor air was performed in March 2017 with paired sub-slab samples (same location) including both VOC and radon sampling. A second round was taken in July 2017 but with no paired soil vapor. The concentrations were lower in the second round. Sampling was performed on the weekend when the offices were closed. I assumed paired sub-slab and indoor air to be within 10-ft of each other for paired locations. Some indoor locations were only sampled for radon or VOCs. Distance between the unpaired samples are roughly estimated since the building diagrams with precise locations (showing the sub-slab) have no scale. There are duplicate samples for both IA-1 and the paired SS-01. I used only the primary sample since presenting the duplicates would result in too many combinations.	

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	TURCO PRODUCTS INC.
Site Address	24700 SOUTH MAIN STREET, CARSON , CA 90745
Oversight Agency	DTSC
Type of Site	VCA/RCRA CACA
Site Documents	

Description of Buildings Subject to Testing

Turco began operations at the site in 1960, and manufactured chemicals for industrial, institutional, and commercial floor finishers, metal cleaners, and paint strippers.

The construction of the first warehouse building (South Bldg) by 1958, including offices & packaging area. In approximately 1968, the large northern warehouse was constructed (North Bldg~54000 ft2 + Middle Bldg~39000 ft2), including offices and storage areas.

Description of Indoor Air Testing

<u>2019 Testing</u>
Air sampling 6/12/19: 2 IA (AA-1/2; AA-3/4/5 not used <= OA levels); 2 OA (AA-6/7)
Soil gas sampling 2/26/19: 3 Interior locations (AB-21/25/26, 5' and 15' bgs); 4 exterior locations (AB-7/30/31/32) not used as the distance to building >= 75 feet
Indoor Air to SG Pairs: 8 (AA-1 & AB-21/25; AA-2 & AB-21/26)

<u>2007 Testing</u> (RFI/HHRA Report dated December 2010)
Air sampling 9/5/07: 10 IA (AA-1 to 10) + 1 OA (AA-11) locations
Interior subslab/Soil Gas locations: SV-25 and SV-27 (slab 8/27/07); SV-31 (slab/5'/15' 9/6/07)
Exterior Soil Gas locations: SV-15 (5' 8/27/07), SV-19 (5'&15' 8/27/07), SV-33 (5'&15' 9/6/07)
[lab reports for SV-15/19/25/27 are not available to verify the results on Table 1 of the RFI Report]
IA to Slab pairs: 10 [IA1*SV25, IA2/3/4/5/6*SV31, IA7/8/9/10*SV27]
IA to SG pairs: 16 [IA2/3/4/5/6*SV31(5&15'), IA7*SV19(5&15'), IA8/9*SV15(5'), IA10*SV33(5&15')

CASE NARRATIVE: SITES IN DTSC'S VAPOR INTRUSION DATABASE	
Site Name	Whitcomb Plating
Site Address	17855 Valley Boulevard, 649 Alderton Avenue, 655 Alderton Avenue
Oversight Agency	DTSC
Type of Site	Tiered Permit Industrial Site

Site Documents

Facility Investigation Report Former Whitcomb Plating, 17855 Valley Boulevard, 649 Alderton Boulevard, 655 Alderton Boulevard, City of Industry, California, prepared by CDR Group, dated April 8, 2019.

Data tables start on page 15 of the PDF.

Description of Buildings Subject to Testing

Three buildings included in soil vapor investigation, 17855 Valley Boulevard, and 649 and 655 Alderton Avenue.

17855 Valle Boulevard: Former laboratory area with offices, approximately 12,500 sq feet, no information encountered regarding type of receptors of age of building.

649 Alderton Ave: Autobody repair shop with offices, approximately 8,400 sq ft, no information on type of receptors or age of building encountered.

655 Alderton Avenue: Used a plating area with lunchroom and adjacent wastewater treatment area. Contained a former 500-gallon AST. Approximately 5,500 sq ft, no information regarding type of receptors or age of building encountered.

[Number of buildings, general size of buildings, type of receptors, age of building]

Description of Indoor Air Testing

Six indoor air samples, 5 indoor air samples including one duplicate sample, and 3 groundwater samples collected in December 2018. No building inventory completed prior to sampling.

[Number of samples, number of sampling events, date of sampling events, results of building inventory]

Pair Information:
Number of Indoor Air to Soil Gas Pairs: 0
Number of Indoor Air to Sub-slab Pairs: 13 Number of Indoor Air to Groundwater Pairs: 7

Elevated concentrations of PCE were detected in subslab and groundwater samples collected, and in indoor air samples.

Appendix 5
Peer Reviewers' Charge Questions

The peer reviewers should consider the following general charge questions for the peer review of DTSC's Vapor Intrusion Attenuation Factor Study.

1. Is the document clear with respect to objectives and purpose? Is there an adequate problem statement? Are the stated objectives and purpose met?

2. Are the strengths and limitations of the study clearly laid out in the documentation?

3. Are you aware of any additional information that would significantly reduce key uncertainties, change the overall findings of, or significantly improve the document? For example, are there other good studies or sources on vapor intrusion attenuation data that you are aware of that were not included?

4. Are the methods used to collect, compile, document, and ensure the quality of the vapor intrusion data adequate and were the methods used appropriately? Is the discussion understandable?

5. Were measurements below reporting limits appropriately treated statistically and considered in the data analysis?

6. Is the method used for screening and filtering data to identify real instances of vapor intrusion sound? Are there alternative approaches that should be used or considered? What might be possible impacts of any alternative methods on the report conclusions?

7. Do the methods used for presenting and comparing attenuation factors from different studies and sites provide useful information for investigating and interpreting vapor intrusion attenuation? Is the discussion on the use of the data understandable? Are there alternative approaches that may provide additional insights?

Charge Question	Study Section	Study Sub-Section	Page Number	Comments/Recommendations